(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 June 2025 (12.06.2025)

WIPO | PCT

(10) International Publication Number
WO 2025/120520 A1

(51) International Patent Classification:
G16H 40/20 (2018.01) *G06Q 50/10* (2012.01)
G06Q 10/06 (2012.01) *G06N 3/0985* (2023.01)
G06Q 50/20 (2012.01)

(21) International Application Number:
PCT/IB2024/062183

(22) International Filing Date:
04 December 2024 (04.12.2024)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

63/605,879	04 December 2023 (04.12.2023)	US
63/641,754	02 May 2024 (02.05.2024)	US
63/661,015	17 June 2024 (17.06.2024)	US
63/661,858	19 June 2024 (19.06.2024)	US
63/717,950	08 November 2024 (08.11.2024)	US
63/718,000	08 November 2024 (08.11.2024)	US
63/719,015	11 November 2024 (11.11.2024)	US

(71) Applicant: **VERB SURGICAL INC.** [US/US]; 5490 GREAT AMERICA PARKWAY, Santa Clara, California 95054 (US).

(72) Inventors: **JEGATHEESWARAN, Shan Gowri**; 5490 Great America Parkway, Santa Clara, California 95054 (US). **DIMONTE, Lela**; 5490 Great America Parkway, Santa Clara, California 95054 (US). **FRYREAR II, Raymond Samuel**; 5490 Great America Parkway, Santa Clara, California 95054 (US). **HAIG, Fiona Middlemiss**; St. Anthony's Road, Leeds Yorkshire LS11 8DT (GB). **HENNEN, Alexandre**; 5490 Great America Parkway, Santa Clara, California 95054 (US). **MOHAN, Vikram**; 5490 Great America Parkway, Santa Clara, California 95054 (US). **PURCELL, Christine**; 5490 Great America Parkway, Santa Clara, California 95054 (US).

(74) Agent: **LANE, David A.** et al.; JOHNSON & JOHNSON, One Johnson & Johnson Plaza, New Brunswick, New Jersey 08933 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO,

(54) Title: EVALUATING PERFORMANCE OF A MEDICAL PROCEDURE BY A MEDICAL PRACTITIONER VIA AN ONLINE COLLABORATIVE MEDICAL PLATFORM

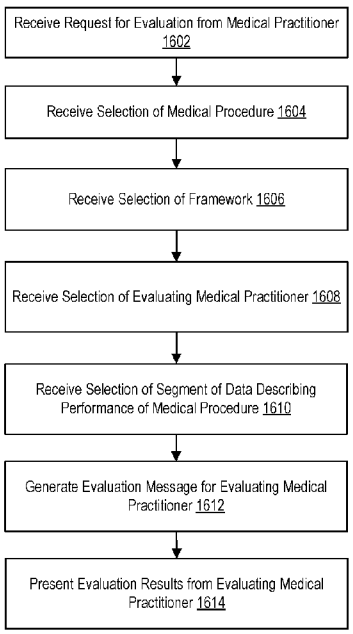

FIG. 16

(57) Abstract: A collaborative medical platform facilitates remote collaboration relating to medical procedures during preprocedural, intraprocedural, and postprocedural stages of a medical case. The collaborative medical platform receives a request from a medical practitioner for evaluation along with a selection of a framework for evaluation and a segment of data describing performance of a medical procedure for evaluation. The collaborative medical platform may transmit an evaluation request including the selected framework and the selected segment to a selected evaluating medical practitioner who provides evaluation results. Alternatively, the collaborative medical platform applies an evaluation model to the selected framework and to the selected segment to automatically generate evaluation results. The evaluation results may be used to select educational content items for the medical practitioner.

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RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

EVALUATING PERFORMANCE OF A MEDICAL PROCEDURE BY A MEDICAL PRACTITIONER VIA AN ONLINE COLLABORATIVE MEDICAL PLATFORM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 63/605,879 filed on December 4, 2023, U.S. Provisional Patent Application No. 63/641,754 filed on May 2, 2024, U.S. Provisional Patent Application No. 63/661,015 filed on June 17, 2024, U.S. Provisional Patent Application No. 63/661,858 filed on June 19, 2024, U.S. Provisional Patent Application No. 63/717,950 filed on November 8, 2024, U.S. Provisional Patent Application No. 63/718,000 filed on November 8, 2024, and U.S. Provisional Patent Application No. 63/719,015 filed on November 11, 2024, the contents of which are each incorporated by reference herein.

BACKGROUND

TECHNICAL FIELD

[0002] The described embodiments relate to a system and method for evaluating performance of a medical practitioner in performing a medical procedure based on data describing the medical procedure captured by a collaborative medical platform.

DESCRIPTION OF THE RELATED ART

[0003] Different techniques employed by medical practitioners when performing medical procedures affect patient results from a medical procedure. To maintain or to improve patient results, data describing a medical procedure is reviewed after completion of the medical procedure to identify techniques employed during the medical procedure that can be improved or refined by a medical practitioner. In many conventional settings, an evaluating medical practitioner is prompted to evaluate a medical practitioner's performance of a medical procedure against one or more frameworks specifying criteria for techniques or skills used during the medical procedure. For example, an evaluating medical practitioner compares performance of a medical procedure by a medical practitioner to standards specified by a framework to evaluate the medical practitioner's performance of the medical procedure. This evaluation may be used to select educational content for the medical practitioner to improve one or more skills or techniques. Similarly, the evaluation may be used to assess changes in performance of one or

more aspects of the medical procedure by the medical practitioner over time. However, evaluating medical practitioners are prompted to evaluate performance of a medical practitioner after performance of a medical procedure. Hence, an evaluating medical practitioner has to rely on their recollection of the medical procedure and of the medical practitioner's performance of the medical procedure to evaluate the medical practitioner. This reliance on an evaluating medical practitioner's memory of a medical procedure increases a difficulty for the evaluating medical practitioner to identify specific areas of improvement for the medical practitioner.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Figure (FIG.) 1 is an example embodiment of a computing environment for an electronically-assisted medical procedure.

[0005] FIG. 2 is a block diagram of an example architecture for a collaborative medical platform.

[0006] FIG. 3A shows a first view of an example practitioner dashboard associated with a collaborative medical platform.

[0007] FIG. 3B shows a second view of an example practitioner dashboard associated with a collaborative medical platform.

[0008] FIG. 4 shows an example practitioner dashboard displaying an educational content item to a medical practitioner associated with a collaborative medical platform.

[0009] FIG. 5 is an example embodiment of a case sharing interface associated with sharing a medical case in the collaborative medical platform.

[0010] FIG. 6 is an example embodiment of a case dashboard associated with a set of cases in a collaborative medical platform.

[0011] FIG. 7 is an example telepresence interface associated with a collaborative medical platform.

[0012] FIG. 8 is another example of a telepresence interface associated with a collaborative medical platform.

[0013] FIG. 9 is an example analytics dashboard associated with a collaborative medical platform.

[0014] FIG. 10 is an example video interface associated with a collaborative medical platform.

[0015] FIG. 11 is an example evaluation interface associated with a collaborative medical platform.

[0016] FIG. 12 is an example framework interface associated with a collaborative medical

platform.

[0017] FIG. 13 is an example evaluator selection interface associated with a collaborative medical platform.

[0018] FIG. 14 is an example segment selection interface associated with a collaborative medical platform.

[0019] FIG. 15 is an example evaluation result interface associated with a collaborative medical platform.

[0020] FIG. 16 is a flowchart of an example embodiment of a process for a medical practitioner obtaining evaluation of performance of a medical procedure by an evaluating medical practitioner via a collaborative medical platform.

DETAILED DESCRIPTION

[0021] The Figures (FIGS.) and the following description describe certain embodiments by way of illustration only. One skilled in the art will readily recognize from the following description that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles described herein. Reference will now be made to several embodiments, examples of which are illustrated in the accompanying figures. Wherever practicable, similar or like reference numbers may be used in the figures and may indicate similar or like functionality.

[0022] A collaborative medical platform facilitates exchange of data between remote medical practitioners in relation to medical cases during preprocedural, intraprocedural, and postprocedural stages. The collaborative medical platform stores or enables access to patient records, imaging data, video data, telemetry data from medical equipment, biometric sensor data from patients, and other medical information that may be obtained prior to medical procedures being performed, during medical procedures, or after medical procedures are performed. Based on data describing performance of a medical procedure that may include video data or telemetry data obtained during performance of the medical procedure, the collaborative medical platform may facilitate evaluation of a medical practitioner's performance of the medical procedure. For example, a medical practitioner selects a medical procedure, a framework for evaluating the medical practitioner, an evaluating medical practitioner, and a segment of data describing performance of the medical procedure. The collaborative medical platform provides the segment of data describing performance of the medical procedure and the framework to the evaluating medical practitioner, who creates evaluation results for the medical practitioner that the collaborative medical platform presents to the medical practitioner. Alternatively, the

collaborative medical platform applies one or more evaluation models to a combination of the segment of data describing performance of the medical procedure and the framework, with an evaluation model generating a predicted portion of evaluation results based on the segment of data describing performance of the medical platform and the framework. Further, the collaborative medical platform may select educational content for the medical practitioner based on the evaluation results for the medical practitioner.

[0023] FIG. 1 illustrates an example embodiment of a computing environment 100 for a collaborative medical platform 140. The collaborative medical platform 140 may include one or more servers that are coupled by a network 130 to client devices 150 associated with users 155 of the collaborative medical platform 140, medical equipment 160, and various third-party servers 170. The collaborative medical platform 140 facilitates collaborative exchange of data between medical practitioners, patients, administrators, or other users 155 via the client devices 150 in support of preprocedural, intraprocedural, and postprocedural stages of medical cases. The collaborative medical platform 140 may furthermore facilitate access to telemetry data from medical equipment 160 (including, for example, real-time video, images, biometric sensing data, equipment control and/or status signals, etc.) that may be utilized in conjunction with performing medical procedures and managing patient cases. Furthermore, the collaborative medical platform 140 may facilitate access to various third-party servers 170 that provide external services such as, for example, electronic healthcare records (EHR) services, medical telepresence services, operating room scheduling, data analytics services, etc.

[0024] To further support the preprocedural stage of a medical case, the collaborative medical platform 140 may select one or more reference content items for presentation to a medical practitioner before performing a medical procedure. In various embodiments, the collaborative medical platform 140 maintains a store or a library of reference content items from which reference content items for the medical practitioner are selected. Alternatively or additionally, one or more third-party servers 170 maintain reference content items, and the collaborative medical platform 140 selects one or more reference content items from a third-party server 170. Reference content items for a medical practitioner may be retrieved from a combination of one or more third-party servers 170 and the collaborative medical platform 140. The collaborative medical platform 140 leverages data in a user profile of a medical practitioner to select one or more reference content items for the medical practitioner.

[0025] In support of an intraprocedural stage of a medical case, the collaborative medical platform 140 may facilitate presentation of various information to support the procedure such as preprocedural images, models, patient data, equipment information, or other data. The collaborative medical platform 140 may furthermore facilitate a telepresence session that enables

one or more remote contributors to access video, images, 3D models, equipment telemetry data, or other data streams capturing during an ongoing medical procedure. The collaborative medical platform 140 may furthermore enable remote practitioners to provide annotations or other commentary related to real-time video, images, or three-dimensional models associated with a procedure. The collaborative medical platform 140 tracks and stores all data from the procedure (including video, medical equipment telemetry, and collaborative commentary) in association with the case identifier to enable subsequent access.

[0026] During the intraprocedural stage, the collaborative medical platform 140 may present educational content about a medical procedure being performed to one or more medical practitioners performing the medical procedure. Educational content describes performance of the medical procedure, such as information about techniques to use, movement of medical instruments or medical equipment, settings for medical equipment, or other information. The collaborative medical platform 140 compares telemetry data or video data of a medical procedure during the intraprocedural stage to baseline criteria associated with educational content and selects educational content associated with baseline criteria from which the telemetry data or video data deviates. Educational content may include instructions that, when executed by a piece of medical equipment 160, modify one or more settings of the piece of medical equipment based on the educational content, simplifying adjustment of operation of the piece of medical equipment 160.

[0027] In support of a postprocedural stage of a medical procedure, the collaborative medical platform 140 enables medical practitioners connected with a case to collaboratively monitor data associated with a patient's recovery. For example, the collaborative medical platform 140 may provide interfaces for viewing health records associated with the patient's recovery and facilitate collaborative exchange between medical practitioners through a case-specific content feed. The collaborative medical platform 140 may furthermore perform various analytics relating to performed medical procedures based on aggregations of data. The analytics may be useful to support patient recovery, to improve future procedures, and to track the performance of medical practitioners.

[0028] Educational content relevant to a medical procedure may be selected and presented to a medical practitioner who performed the medical procedure during the postprocedural stage by the collaborative medical platform 140. For example, metrics or analytics determined for the medical procedure by the collaborative medical platform 140 are compared to baseline criteria for various educational content. In various embodiments, the collaborative medical platform 140 selects educational content associated with baseline criteria from which a metric deviates and presents the selected educational content to the medical practitioner. For example, the

collaborative medical platform 140 includes information identifying selected educational content in one or more interfaces generated for presentation to the medical practitioner, simplifying access to instructional information relative to the medical procedure.

[0029] The collaborative medical platform 140 may intelligently utilize data collected during preprocedural, intraprocedural, and/or postprocedural stages of a case during a different stage of the same case or other cases. For example, annotations of images or 3D models, practitioner comments from a content feed, or other information obtained during a preprocedural stage may be made available in the intraprocedural stage to aid the performing practitioner through the procedure. Analytical data relating to postprocedural data may be utilized to generate recommendations for future procedures, such as educational content, in order to improve efficiencies and/or outcomes.

[0030] The collaborative medical platform 140 may also facilitate functions such as managing clinical trials, facilitating education training and performance tracking, facilitating broadcasts of medical-related presentations, and facilitating procedure scheduling. Beneficially, the collaborative medical platform 140 stores complete records of medical cases (including video and telemetry from procedures) in a centralized and standardized platform that naturally allows for collaboration in an online environment, where practitioners may interact from disparate remote locations. The collaborative medical platform 140 may maintain data in a manner that adheres to data privacy and compliance obligations of medical practitioners and organizations.

[0031] The collaborative medical platform 140 may furthermore employ various machine learning techniques to infer recommendations, insights, or other artificially generated contributions based on the data collected into the collaborative medical platform 140. For example, the collaborative medical platform 140 may generate a recommendation for a medical practitioner to review educational content relevant to a medical practitioner based on data captured by the collaborative medical platform 140 during performance of a medical procedure. For example, the collaborative medical platform 140 selects educational content for a medical practitioner based on telemetry data captured during a medical procedure performed by the medical practitioner. As another example, the collaborative medical platform selects educational content for a medical practitioner based on video data captured during a medical procedure performed by the medical practitioner. Educational content selected by the collaborative medical platform may be video, audio, text, or other data describing performance of a medical procedure. Additionally or alternatively, educational content configuration instructions or configuration data for one or more pieces of medical equipment 160.

[0032] The collaborative medical platform 140 may generate and present other recommendations

to a medical practitioner based on stored information for the medical practitioner. For example, the collaborative medical platform 140 generates a recommendation for the medical practitioner based on a type of procedure scheduled to be performed by the medical practitioner; in various embodiments, the recommendation comprises case records associated with one or more historical cases captured in the collaborative medical platform 140 relating to prior performances of the type of procedure on a similarly situated patient. If granted appropriate permissions, the practitioner may then review an entire case record through the collaborative medical platform 140 including preprocedural information, videos or other data from the procedure itself, and postprocedural outcome data. In another example, the collaborative medical platform 140 may intelligently generate a recommendation to invite a particular medical practitioner to collaborate on a case based on that practitioner having relevant expertise, experience, and/or availability. An invitation may then be generated to the medical practitioner to enable access and collaboration on the case during at least one of the preprocedural, intraprocedural, and postprocedural stages. Furthermore, the collaborative medical platform 140 may intelligently identify and present patient risk factors relevant to procedure performance, planning, and postprocedural care. The collaborative medical platform 140 may also intelligently recommend educational content for training medical practitioners based on their individual tracked performance and various comparative analytics.

[0033] The collaborative medical platform 140 may be implemented using on-site computing or storage systems, cloud computing or storage systems, or a combination thereof and may be implemented utilizing local or cloud-based servers, which may include physical or virtual machines, or a combination thereof. Cloud-based servers may include private cloud systems, public cloud systems, hybrid public/private cloud systems, or a combination thereof. Accordingly, the collaborative medical platform 140 may be local, remote, and/or distributed relative to the medical environments where procedures are performed and relative to the client devices 150 providing user access. Furthermore, different portions of the collaborative medical platform 140 may execute on different remote servers and various system elements of the collaborative medical platform 140 may be communicatively coupled over a network 130.

[0034] The client devices 150 may include, for example, a mobile phone, a tablet, a laptop or desktop computer, other computing device, or application executing thereon for accessing the collaborative medical platform 140 via the network 130. The client devices 150 may enable access to various user interfaces (which may comprise web-based interfaces accessed via a browser or application interfaces accessed via an application) for viewing and/or editing information associated with the collaborative medical platform 140. The client devices 150 may include conventional computer hardware such as a display, input device (e.g., touch screen),

memory, a processor, and a non-transitory computer-readable storage medium that stores instructions for execution by the processor in order to carry out functions described herein. Examples of user interfaces are described in further detail below with respect to FIGs. 3-15.

[0035] The third-party servers 170 may facilitate diverse services utilized by the collaborative medical platform 140. For example, the third-party servers 170 may include various EHR systems for managing patient records, robotic control platforms for controlling surgical robots or other medical equipment, telepresence servers for facilitating telepresence services, patient scheduling systems, hospital information systems (HIS), or other servers. As another example, one or more third-party servers 170 include educational content about various medical procedures, such as articles about various medical procedures, audio data related to medical procedures, video data related to medical procedures, settings or configuration details for medical equipment 160 used in medical procedures, or other descriptive information about medical procedures. The third-party servers 170 may be implemented using various on-site computing or storage systems, cloud computing or storage systems such as private cloud systems, public cloud systems, hybrid public/private cloud systems, or a combination thereof.

[0036] The medical equipment 160 may include various sensors such as cameras or other imaging equipment, biometric monitors, or other sensing devices that collect data associated with a medical procedure being performed. Sensor data may include physiological or biological signals (such as pulse rate, blood pressure, body temperature, etc.), video, electrical signals representative of a state of a medical instruction, or other information. Cameras or image sensors may include still image cameras, video cameras, 3-dimensional (3D) imaging devices, or a combination thereof. The cameras can include stationary cameras in a medical environment (e.g., operating room) or may include cameras integrated into medical instruments such as endoscopic cameras. Imaging systems may include computed tomography (CT) imaging systems, medical resonance imaging (MRI) systems, X-ray systems, or other imaging equipment. The medical equipment may furthermore include a robotic device that facilitates robotically-assisted medical procedures. The robotic device may include, for example, a robotic arm or other computer-controlled mechanical device that performs or assists with a medical procedure. The robotic device may be pre-programmed to perform a certain set of steps or tasks, and/or may be manually controlled by an operator. Telemetry data associated with a robotic device may include force data, positional data, or other sensor data, control signals, fault conditions, or other data relating to operation of the robotic device during a procedure. The medical equipment data may be streamed to the collaborative medical platform 140 in real-time or may be stored on a third-party server 170 and later uploaded to the collaborative medical platform 140.

[0037] The network 130 comprises communication pathways for communication between the

collaborative medical platform 140, the medical equipment 160, the client devices 150, and the third-party servers 170. The network 130 may include one or more local area networks and/or one or more wide area networks (including the Internet). The network 130 may also include one or more direct wired or wireless connections (e.g., Ethernet, WiFi, cellular protocols, WiFi direct, Bluetooth, Universal Serial Bus (USB), or other communication link).

[0038] FIG. 2 is a block diagram showing an example architecture of an embodiment of the collaborative medical platform 140. In the embodiment of FIG. 2, the collaborative medical platform 140 includes a data ingestion module 205, an entity management module 210, an interface management module 215, a medical intelligence module 220, a telepresence module 225, an analytics module 230, a practitioner education module 235, a presentation module 240, an application integration module 245, a video library 250, a connection graph store 255, a user profile store 260, and a patient data store 265. In other embodiments, the collaborative medical platform 140 includes different or additional functional blocks than those shown in FIG. 2. Further, in some embodiments, a single functional block provides the functionality of multiple functional blocks shown in FIG. 2.

[0039] While in one embodiment, the illustrated functional blocks may execute entirely within the collaborative medical platform 140, alternative embodiments may include various modules or discrete functions of modules being executed by one or more third-party servers 170. Here, the collaborative medical platform 140 may interact with a third-party server 170 via an application programming interface (API) to enable the collaborative medical platform 140 to request and utilize services provided by the third-party servers 170 to facilitate any of the functions described herein. For example, in an embodiment, electronic health records may be provided by a third-party server 170. Here, the collaborative medical platform 140 may query the third-party server 170 for relevant data but does not necessarily locally store complete patient records. Furthermore, third-party servers 170 may facilitate services such as telepresence sessions, presentation creation, access to video resources, three-dimensional model generation, or other aspects of the functions of the collaborative medical platform 140 described herein.

[0040] The data ingestion module 205 ingests various medical data used by the collaborative medical platform 140. The data ingestion module 205 may be electronically coupled to one or more external servers, databases, or other data sources that supply the medical data. The medical data may include, for example, profile data for patients (e.g., demographic information, health history, etc.), medical professionals (e.g., expertise, experience, etc.), or facilities, information about medical conditions, procedures, and medications, information about robotic systems, imaging systems, intervention tools, or other medical equipment, information about post-procedural outcomes, or other medical information discussed herein.

[0041] The data ingestion module 205 may aggregate data from various input data sources. For example, the data ingestion module 205 may obtain medical data from conventional electronic health records (EHR) systems. Here, the data ingestion module 205 may perform various pre-processing to normalize data to a standardized format used by the collaborative medical platform 140. For example, medical records may be organized in a database structure that includes values (strings, numerical values, binary values, or other data types) assigned to each of a set of predefined information fields.

[0042] The data ingestion module 205 may furthermore interface with one or more imaging systems to ingest preprocedural, intraprocedural, or postprocedural images, video, or three-dimensional models associated with patients. For example, the data ingestion module 205 may obtain and store X-ray images, magnetic resonance imaging (MRI) images, computed tomography (CT) scan images, visible light images, near infrared fluorescent (NIRF) images, or other medical images, video, or three-dimensional models derived from them. Image data may furthermore include image or video data from one or more cameras present in a medical environment where a medical procedure is being performed, such as one or more overhead cameras and/or one or more endoscopic cameras. Imaging data may include associated metadata such as telemetry data from one or more medical instruments used to perform the medical procedure, annotations or commentary associated with the video received from one or more medical practitioners associated with the medical procedure, segmentation data associated with dividing a video into segments relating to different steps of a procedure, or other information relating to image or video data.

[0043] To simplify subsequent retrieval and review of video of a medical procedure along with associated metadata, the data ingestion module 205 may perform various preprocessing and indexing of the content and associated metadata. For example, the data ingestion module 205 indexes video of a medical procedure with associated metadata to correlate different metadata with different portions of the video, synchronize videos associated with the same medical procedure, or perform various encoding or reformatting of video data. Videos may furthermore be automatically segmented and indexed into video segments corresponding to different steps of a procedure.

[0044] The data ingestion module 205 may furthermore integrate with various robotic platforms or other medical equipment to obtain telemetry data associated with procedures. For example, the data ingestion module 205 may obtain various sensor data from sensors utilized during medical procedures, identifying information associated with medical equipment, control data associated with control a robotic platform or other medical equipment, or other data generated from medical equipment in associated with performed medical procedures.

[0045] The data ingestion module 205 may furthermore provide interfaces accessible via the client device 150 for ingesting data input directly into the collaborative medical platform 140. For example, the data ingestion module 205 may present various forms or freeform entry elements to enable entry of medical information relevant to operation.

[0046] In an embodiment, the data ingestion module 205 may manage data in a manner consistent with various compliance and privacy policies. For example, the data ingestion module 205 may enable removal or redaction of portions of received data to preserve privacy of a patient when the data is used for purposes in which patient identification is not necessary.

[0047] The entity management module 210 manages presentation of entity pages associated with different entities affiliated with the collaborative medical platform 140 and manages connections between entities. Entities may include, for example, users 155 (which may medical practitioners, patients, administrators, etc.), medical cases associated with procedures, facilities, medical equipment 160, files or media content, events (e.g., conferences), presentations, training modules, or other data objects. Entity pages may comprise web pages accessible via a web browser of the client device 150 or may comprise pages of a desktop or mobile application installed on a client device 150.

[0048] Each entity page for an entity may enable viewing of information associated with the entity and/or interactions with the entity. For example, each user 155 of the collaborative medical platform may have a dedicated page that provides information about the user 155 such as identifying information, role (e.g., surgeon, nurse, executive, administrator, patient, etc.) profile information (e.g., biography, credentials, etc.), assigned cases, procedure histories, connections to other users or cases, scheduling information, or other user-specific data. An entity page for a patient (whether or not the patient is a user 155 of the collaborative medical platform 140) may include patient profile information, health history, planned procedures, risk factors, or the medical information associated with the patient. An entity page for a medical case may include information about a patient associated with the case, descriptive information about a medical procedure (such as a type of medical procedure) associated with the case, a medical environment where the medical procedure is to be performed, other descriptive information about the medical procedure, a status of the procedure (e.g., preprocedural stage, intraprocedural stage, or postprocedural stage), or other information relevant to a medical case. Pages may furthermore include various interactive elements (e.g., content feeds) that enable users to share and interact with data associated with that entity as will be further described below.

[0049] The entity management module 210 also organizes pages and associated data received into the collaborative medical platform 140 into a connection graph (stored to the connection

graph store 255) that captures relationships between different entities and associated data. Some connections may be configured as default connections, while other connections may be created based on specific actions from users 155. For example, users 155 may be connected by default to other users 155 (with at least viewing permissions) within the same organization. Alternatively, connections may be generated only when a user 155 expressly invites another user 155 to connect and the receiving user 155 accepts the connection request. Connections between medical practitioners and medical cases may similarly be created by default or in response to invitations to create a connection. For example, a default connection may be created between an entry for a planned medical procedure and a medical practitioner assigned responsibility for the procedure. Alternatively, all medical practitioners within an organization or within a relevant department may become connected to a planned procedure as a default. In other scenarios, a user may share a medical case with one or more other medical practitioners to generate a connection request that invites the other medical practitioners to collaborate with on the medical case. Accepting the connection request may then create a connection between the invited practitioner and the medical case. Supplemental connections may also automatically be generated (e.g., between the owner of the procedure and the invited contributor). Connections may furthermore be created between users 155 and individual videos, files, presentations, or other data objects. For example, a user 155 that creates or owns a video may share the video with one or more other users 155 to grant access rights to the video.

[0050] Connections between entities may be of diverse types and may be governed by different permissions. Generally, pages may be accessed only by users having appropriate access permissions. Different permission levels may dictate distinct levels of access for different pages. For example, depending on user-specific permissions for a particular page, the user may be permitted or blocked from accessing the data, editing the data, commenting or annotating the data, deleting the data, or performing other modifications. In an embodiment, a page may have a page owner with the highest level of access permissions. Generally, a medical practitioner may be the page owner for their own profile page and for procedures for which they have primary responsibility. Pages associated with facilities, medical equipment, or other entities may variably be owned by an assigned medical practitioner. Non-owners may have distinct levels of access to pages depending on the configured permissions. Permissions may be granted by the page owner or by another user that has appropriate permissions to assign or relinquish permissions to other users.

[0051] Based on different connections available to different users 155, the collaborative medical platform 140 enables a personalized experience for each user 155. For example, upon logging into the collaborative medical platform 140, a user 155 may be presented with personalized

interfaces that relate to their connections to other users 155, medical cases, videos, presentations, or other content hosted by the collaborative medical platform 140.

[0052] An interface management module 215 manages content associated with various interfaces hosted by the collaborative medical platform 140 and accessible via the client devices 150. As described above, the interface management module 215 may manage pages associated with the various entities managed by the collaborative medical platform 140 including users 155 (which may include medical practitioners, patients, administrators, etc.), medical cases associated with procedures, facilities, medical equipment 160, files or media content, events (e.g., conferences), presentations, training modules, or other data objects. Access to different pages by a specific user 155 may be dependent on that user's connections and permissions configured in the connection graph store 255. Furthermore, patient data may be pseudonymized for viewing by certain other users (dependent on the type of connection and/or permission) such that the patient data cannot be attributed to a specific individual.

[0053] A medical case page associated with a medical case may include information organized into preprocedural, intraprocedural, and postprocedural stages. At the preprocedural stage, a medical case page may include information about the patient, the procedure being performed, and the medical practitioner performing the procedure. The interface management module 215 may furthermore provide access to various analytical information (e.g., generated by the analytics module 230 described below) such as risk factors for the patient, experience/expertise of the medical practitioner, outcomes for the type of procedure being planned, or other data. At the intraprocedural stage, the medical case page may provide access to a telepresence session to enable remote collaborators to remotely collaborate with respect to an ongoing procedure. At a postprocedural stage, the medical case page may include information about the patient treatment plan, risk factors, follow up visits, or other postprocedural information.

[0054] Some entity pages in the collaborative medical platform 140 may include content feeds to facilitate collaboration between users 155. Content feeds may include various content (e.g., posts) such as text-based commentary, images, video, three-dimensional models, or other multimedia content relating to a medical case. Content may be directly posted to a page associated with a medical case or a post may comprise links to content stored by the collaborative medical platform 140 or on an external server. Posts may be grouped into conversations that hierarchically track the relationships between posts. For example, posts may be made as original posts (which start a new conversation) or as replies to existing posts (which become part of the conversation).

[0055] In an example use, a user 155 may invite one or more other users 155 to collaborate on a

medical case and thereby gain access to a case page for the medical case. A content feed on the page enables the collaborating users 155 to post to the case page in association with the medical case. The content feed may therefore enable discussion about the procedure to be performed discussion of risk, best practices, or other information that may be useful to the practitioner performing the procedure. Furthermore, the contributing users 155 may post videos or three-dimensional models (or links to content) relating to historical procedures for similarly situated patients. Additionally, contributing users 155 could share links to entity pages associated with past procedures that may be of relevance, to enable a performing medical practitioner to view historical content feeds associated with those procedures. Patient data may optionally be pseudonymized when shared with other users (dependent on the type of connection and/or permission) such that the patient data cannot be attributed to a specific individual.

[0056] Content feeds may furthermore be utilized in relation to an ongoing procedure during a real-time telepresence session as discussed in further detail below. Here, a content feed may be presented as a real-time chat window that enables contributors to comment during a procedure, share video, images, or other media, provide links to relevant resources, or otherwise contribute content during the course of procedure.

[0057] In a postprocedural stage, a content feed may be utilized by contributors to discuss postprocedural treatments, patient recovery, risk management, or other information relevant to patient recovery. Examples of content feeds are provided in FIG. 7 which are described in further detail below.

[0058] The medical intelligence module 220 generates medical intelligence data that may be automatically added to content feeds or otherwise made available in the context of the collaborative medical platform 140. For example, the medical intelligence module 220 may automatically contribute posts to a content feed for a medical case that an artificial intelligence agent infers is relevant. Artificially generated posts may mimic posts provided by human contributors and may include text-based commentary, multimedia, links, etc. Medical intelligence data may be generated during a preprocedural stage, during a procedure, or during a postprocedural stage.

[0059] In an example implementation, the medical intelligence module 220 may include one or more machine-learned models trained to generate content that the models infer to be relevant to a particular medical case or more generally relevant to a user 155. In one implementation, the machine learned model generates an embedding for a medical case based on descriptive information about a medical procedure, characteristics of the patient on whom the medical procedure is to be performed, characteristics of medical practitioner performing the procedure,

posts in the content feed, or other information available in the collaborative medical platform 140. The medical intelligence module 220 determines measures of similarity (e.g., cosine similarity, dot product) between the embedding for the medical case and embeddings for other content available in the collaborative medical platform 140 and that can be included in automated posts. The medical intelligence module 220 may then generate posts and/or select content for posts based on similarities of the embeddings. The medical intelligence module 220 may furthermore employ various Large Language Models (LLMs) to analyze text-based content associated with a medical case and artificially generate relevant natural language content for the content feed. Machine learning models may furthermore include one or more neural networks (such as convolutional neural network (CNN), artificial neural network (ANN), residual neural network (ResNet), or recurrent neural network (RNN)), regression-based models, generative models, or other type of machine-learned model capable of achieving the functions described herein.

[0060] In an example use case, the medical intelligence module 220 may identify one or more historical medical cases that are similar to a current medical case and automatically generate a link to a case page for the related case. A medical practitioner may then view videos, models, or other recorded data associated with the related medical case to help the practitioner prepare for a procedure. In other examples, the medical intelligence module 220 may automatically respond to a question posed by a user in the content feed. For example, the medical intelligence module 220 may operate like a chatbot that intelligently responds to text-based queries. In further embodiments, the medical intelligence module 220 may generate a recommendation to invite a specific medical practitioner to collaborate on a medical case based on relevant expertise and experience. A user may then select to invite the recommended collaborator to collaborate on the medical case based on the artificially generated recommendation.

[0061] The telepresence module 225 facilitates a telepresence session during a procedure. The telepresence session may be joined by one or more collaborators that have been invited to collaborate on the medical case and enable the other users 155 to remotely access video, telemetry data from one or more medical instruments, or other real-time data captured during a medical procedure. As described above, a content feed may also be displayed in association with the telepresence session to enable contributors to comment or share multimedia or links relevant to the procedure.

[0062] The telepresence module 225 may furthermore enable contributors to provide real-time annotations on images, video, three-dimensional models, or other visual content of anatomy relevant to an ongoing procedure. For example, a contributor may mark locations in the visual content in association with provided comments. The telepresence module 225 may furthermore

enable contributors to add overlaid drawings, highlighting, or other visual indicators during an ongoing telepresence session.

[0063] In an embodiment, the telepresence module 225 may enable remote contributors to take control of medical equipment 160. For example, a remote contributor may access a control interface that provides control elements for controlling a position or orientation of a camera, controlling a robotic arm, setting a configuration of a sensing device, or performing other control functions of medical equipment.

[0064] Upon completing a procedure, the telepresence module 225 may store the recorded video, telemetry data, content feed, annotations, and other captured data in association with the procedure. This information may be later accessed by users 155 of the collaborative medical platform 140 (with appropriate permissions) and/or may be utilized by the medical intelligence module 220 to further train machine learning models and/or generate inferences.

[0065] The analytics module 230 facilitates generation of various statistics, metrics, or other analytics associated with information stored in the collaborative medical platform 140. Analytics may generally be created based on a set of filtering parameters that yield some subset of data records for aggregating, and a combining function that specifies how the filtered data should be combined. The filtering parameters may filter medical procedure data based on data fields such as patient data, medical practitioner data, facility, procedure type, medical equipment used, etc. The combining function may comprise, for example, an averaging function, a median function, a histogram function, or other function. A specific analytics function may result in a single output value or a series of values over one or more dimensions. Series outputs may be visually represented in a table, chart, graph, or other visual output.

[0066] For example, the analytics module 230 may generate metrics describing an average length of time for a specific medical practitioner or a group of medical practitioners to complete a medical procedure. Average times for various procedures performed by the same medical practitioner or group of practitioners may be presented together with similar metrics for other medical practitioners for comparison purposes. In another example, the analytics module 230 may generate metrics describing a number of times a medical practitioner has historically performed a specific type of medical procedure. Such counts could be further aggregated to indicate percentages that reflect how many times a medical practitioner has performed each different type of medical procedure out of a total number of procedures performed.

[0067] In further embodiments, the analytics module 230 may generate analytics based on interactions of the medical practitioner in the collaborative medical platform 140. For example, statistics can be derived based on counts of posts, comments, or other content contributed by a

medical practitioner to the collaborative medical platform 140. Such analytics may be expressed in terms of counts of interactions, frequency of interactions, or other aggregations. These analytics could furthermore be separately aggregated based on whether interactions relate to pre-procedural, intra-procedural, or post-procedural phases of procedures.

[0068] In an embodiment, the analytics module 230 may generate analytics based on specific filtering and/or combining functions specified by a user 155 of the collaborative medical platform 140. Additionally, the analytics module 230 may include various preset analytics that may be generated without necessarily receiving specific user inputs. Furthermore, in some embodiments, the medical intelligence module 220 may automatically generate analytics that it infers will be relevant to a specific user 155.

[0069] In some embodiments, the analytics module 230 may generate analytics based on any aspects of the collective case data including preprocedural data, telepresence sessions data (including recorded video, telemetry data, in-session content feed data, etc.), and postprocedural data. Analysis associated with telepresence session data may include performing various video processing, content recognition, or other advanced image processing techniques to extract useful information from videos. Furthermore, the analytics module 230 may leverage various medical intelligence data generated from the medical intelligence module 220 to generate analytics.

[0070] The practitioner education module 235 manages and stores training data for medical practitioners associated with medical procedures. In various embodiments, the training data comprises educational content including descriptive information about a medical procedure or about a portion of a medical procedure. Example educational content includes training videos relating to performing medical procedures, articles about performing medical procedures, articles or videos about using one or more pieces of medical equipment 160 in a medical procedure, articles or videos about using one or more medical instruments in a medical procedure, best practices for a medical procedure, training manuals for medical procedures, instructional material for one or more medical instruments used in a medical procedure, digital training modules, webinars, audio data about a medical procedure (e.g., a podcast about a medical procedure) or other information for training medical practitioners in relation to medical procedures.

[0071] In various embodiments, educational content also includes configuration data or configuration instructions for one or more pieces of medical equipment 160 used in one or more medical procedures. For example, educational content includes a set of configuration instructions for configuring or for calibrating a robotic arm or other piece of medical equipment 160 for use in a medical procedure. Configuration instructions may include one or more settings

for the piece of medical equipment 160. Example settings include: one or more limiting values for an amount of force applied by a piece of medical equipment 160, one or more limiting values for a range of motion of a piece of medical equipment 160, one or more limiting values for an amount of energy supplied by a piece of medical equipment 160, an identifier of a mode of operation for a piece of medical equipment 160, or values for one or more other settings of a piece of medical equipment 160. As another example, educational content comprises a set of instructions that, when executed by a piece of medical equipment 160, cause the piece of medical equipment 160 to perform a sequence of actions for calibration. Certain educational content may be executable by a piece of medical equipment 160 to modify values of one or more settings of the piece of medical equipment 160 or a mode of operation of the piece of medical equipment 160, allowing automatic modification of one or more settings of the piece of medical equipment 160 via the educational content item without a medical practitioner manually specifying values of settings of the piece of medical equipment 160.

[0072] The practitioner education module 235 stores educational content as different educational content items, with each educational content item comprising a discrete portion of content, such as a file. Each educational content item has one or more attributes providing descriptive information about the educational content item. For example, an attribute of an educational content item identifies one or more types of medical procedures associated with the educational content item, allowing identification of educational content items corresponding to different types of medical procedures. Other example attributes of an educational content item include: one or more medical practitioners associated with the educational content item (e.g., a medical practitioner who performed a medical procedure associated with the educational content item, a medical practitioner who created the educational content item), a location associated with the educational content item (e.g., a geographic location, a specific medical facility), a time associated with the educational content item (e.g., a time when the educational content item was created), identifiers of one or more pieces of medical equipment 160 associated with the educational content item, identifiers of one or more medical instruments used in a medical procedure associated with the educational content item, a format of the educational content item (e.g., audio, video, text), or other information describing the educational content item. Educational content items may be locally stored by the collaborative medical platform 140 (e.g., in the video library 250 or another storage device) or retrieved from one or more third-party servers 170 in various embodiments.

[0073] One or more educational content items may comprise reference cases, which are medical cases that a medical practitioner who performed a completed medical procedure in a medical case selected to be available to other medical practitioners. For a reference case, the practitioner

education module 235 stores video data, telemetry data from medical equipment 160, or other data captured by the collaborative medical platform 140 during performance of the completed medical procedure. In various embodiments, a reference case includes a content feed including comments or other data obtained by the collaborative medical platform 140 from contributors during the completed medical procedure. For a reference case, the practitioner education module 235 pseudonymizes patient data to prevent the reference case from including patient data capable of being attributed to a specific patient. In some embodiments, the pseudonymized patent data in a reference case identifies ranges for one or more types of patent data to maintain relevant information about a patent on whom the completed medical procedure was performed for another medical practitioner while preventing identification of a specific patient on whom the completed medical procedure was performed.

[0074] Each educational content item is associated with one or more baseline criteria. Different baseline criteria specify values for metrics from performing a medical procedure, settings for a piece of medical equipment 160 used for a medical procedure, movement patterns of a piece of medical equipment 160 during a medical procedure, patterns of telemetry data obtained during a medical procedure, movement patterns of a medical practitioner during a medical procedure, or other descriptive information about performing a medical procedure. A baseline criterion specifies a standardized value for a metric, a standardized technique or approach used in a medical procedure, or other standardized value or technique related to a medical procedure. The practitioner education module 235 maintains one or more baseline criteria for different medical procedures, so different educational content items correspond to different medical procedures. An attribute of an educational content item comprises an identifier of a type of medical procedure to indicate the educational content item and its associated baseline criteria correspond to the type of medical procedure. This allows the practitioner education module 235 to identify different baseline criteria for different types of medical procedures.

[0075] In various embodiments, one or more medical practitioners input baseline criteria for a medical procedure to the practitioner education module 235. For example, a group of medical practitioners reach a consensus on values of metrics, patterns of telemetry data, patterns of movement, or values of other information describing performance of a medical procedure. A medical practitioner of the group inputs the agreed-upon baseline criteria to the practitioner education module 235 for storage in association with an educational content item. The group of medical practitioners may be associated with a particular medical facility (e.g., a hospital, a clinic), to provide facility-specific baseline criteria. The practitioner education module 235 stores an identifier of a medical facility as an attribute of an educational content item associated with the facility-specific baseline criteria to indicate baseline criteria associated with a specific

medical facility. Additionally or alternatively, the group of medical practitioners who determined baseline criteria are not associated with a particular medical facility, but correspond to a larger organization or standards body, so the baseline criteria for the medical procedure are applicable across various medical facilities. The practitioner education module 235 may store facility-specific baseline criteria and more generally applicable baseline criteria as different attributes of an educational content item in various embodiments. This allows augmentation of more generally applicable baseline criteria associated with an educational content item with facility-specific baseline criteria.

[0076] In various embodiments, the practitioner education module 235 generates one or more baseline criteria associated with an educational content item by applying one or more trained machine learned models to metrics generated for multiple medical cases in which a type of medical procedure was performed by the analytics module 235. In various embodiments, the one or more trained machined learned models are also applied to telemetry data or video data captured by the telepresence module 225 during medical cases where the type of medical procedure was performed. For example, a machine learned model detects patterns in telemetry data captured during medical procedures of a specific type occurring in medical cases for which a specific value of a generated metric was generated or for which a value of a generated metric is within a range of values. The specific value of a generated metric or a range of values of the generated metric may correspond to one or more specific patient outcomes. For example, the specific value or range of values identifies successful patient outcomes for the type of medical procedure. One or more patterns of telemetry data detected with at least a threshold frequency in medical procedures occurring in medical cases for which the generated metric has the specific value or has a value within a specified range are stored as baseline criteria for an educational content item associated with the specific type of medical procedure in various embodiments.

[0077] For example, application of a machine learned model to telemetry data identifies a specific sequence of movement of a piece of medical equipment 160 detected with at least a threshold frequency in completed medical procedures of the specific type performed in medical cases a metric corresponding to a positive outcome are stored as baseline criteria for an educational content item corresponding to movement of the piece of medical equipment 160 for the specific type of medical procedure. Telemetry data describing the specific sequence of movement of the piece of medical equipment 160 may be stored in the educational content item to specify limits of movement of the piece of medical equipment 160 during the specific type of medical procedure or to specify limits on force applied by the piece of medical equipment 160 during the specific type of medical procedure. As another example, captured telemetry data includes positional data for a piece of medical equipment 160 during occurrences of the type of

medical procedure occurring in medical cases with one or more metrics correlated with positive outcomes for a patient. The practitioner education module 235 stores an educational content item associated with the type of medical procedure having the positional data in the captured telemetry data as a baseline criterion. This allows the practitioner education module 235 to dynamically generate an educational content item and associated baseline criteria for a type of medical procedure based on telemetry data captured during performance of the type of medical procedure over time, simplifying generation of educational content items for various medical procedures.

[0078] In other examples of generating educational content item from telemetry data, telemetry data from a piece of medical equipment includes bimanual dexterity of the medical practitioner during a medical procedure, with the bimanual dexterity information stored in an educational content item as baseline criteria in response to determining the medical procedure had a positive outcome. In various embodiments, the generated educational content item includes data for accessing a simulator for the piece of medical equipment 160 used during the medical procedure (e.g., an identifier of a simulator, one or more exercises or techniques to perform on the identified simulator, etc.) to further refine use of the piece of medical equipment 160 in response to telemetry data from a medical practitioner during a medical procedure including bimanual dexterity information deviating from the baseline criteria of the educational content item by at least a threshold amount. As another example, telemetry data from a piece of medical equipment 160 includes tissue tension for a patient during a medical procedure, with the tissue tension stored in an educational content item as baseline criteria in response to the practitioner education module 235 determining the medical procedure had a positive outcome. The generated educational content item may include data for accessing a simulator for the piece of medical equipment 160 used during the medical procedure (e.g., an identifier of a simulator, one or more exercises or techniques to perform on the identified simulator, etc.) to further refine use of the piece of medical equipment 160 in response to telemetry data from a medical practitioner during a medical procedure including bimanual dexterity information deviating from the baseline criteria of the educational content item by at least a threshold amount.

[0079] Additionally or alternatively, the practitioner education module 235 applies one or more machine learned models to video data captured during performances of a specific type of medical procedure during prior medical cases to identify different pieces of medical equipment 160 used during the specific type of medical procedure, movement of different pieces of medical equipment 160 during the specific type of medical procedure, movement of the medical practitioner performing the specific type of medical procedure, or other information about performing the specific type of medical procedure. As further described above, applying a

machine learning model to video data of prior performances of the specific type of medical procedure detects patterns of movement of the medical practitioner or of a piece of medical equipment 160 during performance of the specific type of medical procedure. A pattern or movement detected with at least a threshold frequency in video data of completed medical procedures of the specific type performed in medical cases having a metric corresponding to a positive outcome are stored as baseline criteria for one or more educational content items associated with the specific type of medical procedure. Such an educational content item associated with the type of medical procedure and baseline criteria describing a pattern of movement includes positional data or other data describing movement or positioning of the medical practitioner or for a piece of medical equipment 160 during the specific type of medical procedure for subsequent reference. Other information, such as depth perception data, proximity of a piece of medical equipment 160 to a structure of the patient, an angle of transection of a structure of a patient by a piece of medical equipment 160, path length of a piece of medical equipment 160, tissue tension, bimanual dexterity of a medical practitioner, or other data may be determined from video data by the practitioner education module 235 and stored as baseline criteria in response to being determined from video data of a medical procedure with a threshold frequency or in response to being determined from video data of a medical procedure having a metric corresponding to a positive outcome. This allows the practitioner education module 235 to determine baseline criteria for a type of medical procedure based on video data of one or more medical procedures.

[0080] To select an educational content item for a medical practitioner, the practitioner education module 235 compares data describing performance of a medical procedure performed by the medical practitioner to baseline criteria associated with various educational content items. In various embodiments, after the medical practitioner completes the medical procedure, the practitioner education module 235 identifies educational content items associated with a type of the medical procedure and compares obtained information describing the medical procedure to one or more baseline criteria associated with the identified educational content items. For example, the practitioner education module 235 compares a metric generated for the medical procedure by the analytics module 230 from captured telemetry data, video data, or other data to a baseline criterion associated with educational content items associated with the type of the medical procedure. In response to the metric differing from the baseline criterion associated with an educational content item by at least a threshold amount, or otherwise failing to satisfy the baseline criterion, the practitioner education module 235 selects the educational content item associated with the baseline criterion for presentation to the medical practitioner. For example, in response to determining an amount of time for the medical practitioner to complete a medical

procedure exceeds an average amount of time to complete the type of medical procedure or exceeds a baseline amount of time to complete the type of medical procedure, and selects one or more educational content items associated with the type of medical procedure and associated with baseline criteria specifying an amount of time to complete the type of medical procedure. In some embodiments, the practitioner education module 235 selects one or more educational content items associated with a type of medical procedure and associated with baseline criteria from which a metric determined for the medical procedure differs by at least a threshold amount, allowing the practitioner education module 235 to account for a specific amount of variance between a determined metric and a baseline criterion when selecting an educational content item.

[0081] Alternatively or additionally, the practitioner education module 235 compares one or more patterns or data detected within telemetry data captured during performance of the medical procedure to baseline criteria associated with educational content items. The practitioner education module 235 selects an educational content item associated with the type of the medical procedure and associated with a baseline criterion specifying a pattern of telemetry data differing from the captured telemetry data by at least a threshold amount. For example, telemetry data includes depth perception data during the medical procedure, and the practitioner education module 235 selects an educational content item associated with the type of the medical procedure and associated with depth perception data differing from the captured depth perception data by at least a threshold amount. The selected educational content item includes information for accessing a simulator for the piece of medical equipment 160 (e.g., an identifier of a simulator, one or more exercises or techniques to perform on the identified simulator, etc.) to be accessed by the medical practitioner in some embodiments. In another example, telemetry data includes tissue tension data captured during the medical procedure, and the practitioner education module 235 selects an educational content item associated with the type of the medical procedure and associated with tissue tension data differing from the captured tissue tension data by at least a threshold amount. The selected educational content item includes information for accessing a simulator for the piece of medical equipment 160 (e.g., an identifier of a simulator, one or more exercises or techniques to perform on the identified simulator, etc.) to be accessed by the medical practitioner in various embodiments.

[0082] Telemetry data from one or more sensors (e.g., sensors included in a piece of medical equipment 160) may also describe movement or positioning of medical equipment 160 or medical instruments during a medical procedure, and the practitioner education module 235 selects an educational content item including baseline criteria from which the movement of a piece of medical equipment or the positioning of a medical instrument in the telemetry data deviates by at least a threshold amount. For example, telemetry data includes a path length of a

piece of medical equipment 160 during the medical procedure, and the practitioner education module 235 selects an educational content item associated with the type of medical procedure and including baseline criteria specifying a path length of the piece of medical equipment 160 from which the path length in the captured telemetry data deviated by at least a threshold amount. As another example, telemetry data includes positional data of a piece of medical equipment 160 during the medical procedure, and the practitioner education module 235 selects an educational content item associated with the type of medical procedure and including baseline criteria specifying positional data of the piece of medical equipment 160 from which the positional data of the piece of medical equipment 160 in the captured telemetry data deviated by at least a threshold amount. In an additional example, telemetry data includes bimanual dexterity data of the medical practitioner during the medical procedure, and the practitioner education module 235 selects an educational content item associated with the type of medical procedure and including baseline criteria specifying bimanual dexterity data of the piece of medical equipment 160 from which the bimanual dexterity data in the captured telemetry data deviated by at least a threshold amount. In the preceding examples, an educational content item selected based on the telemetry data includes information for accessing a simulator (e.g., through the collaborative medical platform 140) associated with the piece of medical equipment 160 corresponding to the telemetry data, providing the medical practitioner with increased interaction with the piece of medical equipment 160. Further, an educational content item selected based on deviation in positional data of a piece of medical equipment 160 from baseline criteria may include one or more of: a training video associated with the piece of medical equipment 160 and describing operation of the piece of medical equipment, audio data describing operation of the piece of medical equipment 160, and information for accessing a simulator for the piece of medical equipment 160 (e.g., an identifier of a simulator, one or more exercises or techniques to perform on the identified simulator, etc.). In some embodiments, the captured telemetry data describes a usage pattern of a piece of medical equipment 160 during the medical procedure. In response to determining the usage pattern of the piece of medical equipment 160 deviates from a baseline usage pattern of the piece of medical equipment in an educational content item, the practitioner education module 235 selects the educational content item, which may include benchmarking data describing a cost of the medical procedure based on the usage pattern and information about alternative usage patterns of the piece of medical equipment 160 to reduce the cost or information describing recommended usage patterns of the piece of medical equipment 160 or use of alternative pieces of medical equipment 160 in the type of medical procedure.

[0083] In various embodiments, the practitioner education module 235 compares one or more data identified from video data captured during performance of the medical procedure to baseline

criteria associated with educational content items to select one or more educational content items for a medical practitioner. The practitioner education module 235 selects an educational content item associated with the type of the medical procedure and associated with a baseline criterion specifying specific data differing from the data identified from the captured video by at least a threshold amount. For example, the practitioner education module 235 obtains depth perception data during the medical procedure from video data of the medical procedure and selects an educational content item associated with the type of the medical procedure and associated with depth perception data differing from the depth perception data determined from the video data of the medical procedure by at least a threshold amount. The selected educational content item includes information for accessing a simulator for the piece of medical equipment 160 (e.g., an identifier of a simulator, one or more exercises or techniques to perform on the identified simulator, etc.) to be accessed by the medical practitioner in some embodiments. In another example, the practitioner education module 235 determines tissue tension data during the medical procedure and selects an educational content item associated with the type of the medical procedure and associated with tissue tension data differing from the tissue tension data determined from the video data by at least a threshold amount. The selected educational content item includes information for accessing a simulator for the piece of medical equipment 160 (e.g., an identifier of a simulator, one or more exercises or techniques to perform on the identified simulator, etc.) to be accessed by the medical practitioner in various embodiments.

[0084] The practitioner education module 235 determines movement or positioning of medical equipment 160 or medical instruments during a medical procedure from video data of the medical procedure through one or more computer vision models or other models in various embodiments. Based on the movement or positioning information obtained from the video data, the practitioner education module 235 selects an educational content item including baseline criteria from which the movement of a piece of medical equipment or the positioning of a medical instrument in the telemetry data deviates by at least a threshold amount. For example, the practitioner education module 235 determines a path length of a piece of medical equipment 160 during the medical procedure from video data of the medical procedure, and the practitioner education module 235 selects an educational content item associated with the type of medical procedure and including baseline criteria specifying a path length of the piece of medical equipment 160 from which the path length from the video data deviated by at least a threshold amount. As another example, the practitioner education module 235 determines positional data of a piece of medical equipment 160 during the medical procedure from video of the medical procedure, and the practitioner education module 235 selects an educational content item associated with the type of medical procedure and including baseline criteria specifying

positional data of the piece of medical equipment 160 from which the positional data of the piece of medical equipment 160 from the video data deviated by at least a threshold amount. In an additional example, the practitioner education module 235 determines bimanual dexterity data of the medical practitioner during the medical procedure from the video data, and the practitioner education module 235 selects an educational content item associated with the type of medical procedure and including baseline criteria specifying bimanual dexterity data of the piece of medical equipment 160 from which the bimanual dexterity data determined from the video data deviated by at least a threshold amount. In the preceding examples, an educational content item selected based on the telemetry data includes information for accessing a simulator (e.g., an identifier of a simulator, one or more exercises or techniques to perform on the identified simulator, etc.) associated with the piece of medical equipment 160 corresponding to the telemetry data, providing the medical practitioner with increased interaction with the piece of medical equipment. Further, an educational content item selected based on deviation in positional data of a piece of medical equipment 160 from baseline criteria may include one or more of: a training video associated with the piece of medical equipment 160 and describing operation of the piece of medical equipment, audio data describing operation of the piece of medical equipment 160, and information for accessing a simulator for the piece of medical equipment 160 (e.g., an identifier of a simulator, one or more exercises or techniques to perform on the identified simulator, etc.).

[0085] In some embodiments, the practitioner education module 235 determines an angle at which a structure of a patient (e.g., an organ of the patient) is transected by a piece of medical equipment 160 (or by a medical instrument) during the medical practitioner form the video data of the medical procedure. The practitioner education module 235 selects an educational content item associated with the type of medical procedure and including an angle for transecting the structure of the patient from which the determined angle from the video data of the medical procedure deviated by at least a threshold amount. An educational content item selected based on deviation of a determined angle of transection of a structure of the patient from a baseline angle of transection may include content describing usage of the piece of medical equipment 160 (or medical instrument) transecting the structure of the patient during the medical procedure or content describing correlations between the angle of transection of the structure of the patient and one or more outcomes of the medical procedure (e.g., information depicting correlation between certain angles of transecting the structure of the patient and positive outcomes of the medical procedure or correlations between angles of transecting the structure of the patient and negative outcomes of the medical procedure). As another example, the practitioner education module 235 determines a proximity of a piece of medical equipment 160 (or a medical

instrument) to one or more critical structures (e.g., an organ, a bone, an artery) of the patient during the medical procedure from video data of the medical procedure. The practitioner education module 235 selects an educational content item associated with the type of medical procedure and including a baseline proximity of the piece of medical equipment 160 (or medical instrument) from the critical structure of the patient from which the proximity of the piece of medical equipment 160 (or medical instrument) from the video data deviated by at least a threshold amount. In various embodiments, the educational content item with the baseline proximity to the critical structure of the patient includes content describing use of energy devices during medical procedures, which may include interactive content (e.g., content with questions to be answered by the medical practitioner), video or audio content describing use of energy devices during medical procedures, or other descriptive information about use of energy devices during medical procedures.

[0086] Further, the practitioner education module 235 may determine a usage pattern of a piece of medical equipment 160 during the medical procedure from video data of the medical procedure. In response to determining the usage pattern of the piece of medical equipment 160 deviates from a baseline usage pattern of the piece of medical equipment in an educational content item, the practitioner education module 235 selects the educational content item. The selected educational content item may include benchmarking data describing a cost of the medical procedure based on the usage pattern and information about alternative usage patterns of the piece of medical equipment 160 to reduce the cost. As another example, the selected educational content item may include information describing recommended usage patterns of the piece of medical equipment 160 or use of alternative pieces of medical equipment 160 in the type of medical procedure.

[0087] In another example, the practitioner education module 235 compares one or more patterns of movement (e.g., movement of a piece of medical equipment 160, movement of a portion of the medical practitioner) detected within video data captured during the medical procedure to baseline criteria including a pattern of movement for the type of the medical procedure and selects an educational content item for the medical practitioner associated with a baseline criterion specifying a pattern of movement from which the detected pattern of movement differs by at least a threshold amount. Hence, the practitioner education module 235 may use data (e.g., video data or telemetry data) captured during performance of a medical procedure to determine when to select an educational content item for the medical practitioner. Different detected patterns within telemetry data or video data captured during performance of a medical procedure may be compared to different educational content items each associated with different baseline criteria. This allows the practitioner education module 235 to select an

educational content item for a medical practitioner based on specific portions of the medical procedure that deviated from a corresponding baseline criterion based on video data or telemetry data captured during performance of a medical procedure, allowing tailoring of educational content item selection to specific portions of the medical procedure.

[0088] The practitioner education module 235 may apply one or more trained machine learning models to data describing performance of a medical procedure performed by the medical practitioner and to attributes of educational content items, such as educational content items associated with a type of the medical procedure, to select one or more educational content items for presentation to the medical practitioner. Example attributes of an educational content item include: a type of medical procedure associated with the reference content item, one or more medical practitioners associated with the reference content item, a location where the medical procedure was performed (e.g., a geographic location, an identifier of a medical facility), a format of the reference content item (e.g., text data, audio data, video data, etc.), feedback about the reference content item from or more medical practitioners (e.g., a rating, an amount of positive feedback received for the reference content item, etc.), or other descriptive information. The practitioner education module 235 trains one or more machine-learning models to select one or more educational content items for a medical practitioner based on attributes of educational content items and characteristics of the medical practitioner in various embodiments. Example machine learning models include regression models, support vector machines, naïve Bayes, decision trees, k nearest neighbors, random forest, boosting algorithms, k-means, and hierarchical clustering. The machine learning models may also include neural networks, such as perceptrons, multilayer perceptrons, convolutional neural networks, recurrent neural networks, sequence-to-sequence models, generative adversarial networks, or transformers, while other types of machine learning models may additionally or alternatively be trained or applied by the practitioner education module 235 in various embodiments.

[0089] For example, to train a machine learning model to select one or more educational content items, the practitioner education module 235 generates a set of training examples, with each training example including data describing performance of a medical procedure performed by a medical practitioner and attributes of an educational content item and having a label indicating whether the medical practitioner in the training example accessed the educational content item included in the training example (or indicating whether the medical practitioner in the training example provided positive feedback for the educational content item included in the training example).

[0090] Applying the machine learning model to a training example generates a predicted likelihood of the medical practitioner in the training example accessing the educational content

item in the training example (or a predicted likelihood of the medical practitioner in the training example providing positive feedback for the educational content item included in the training example). For each training example to which the practitioner education module 235 applies the machine learning model, the practitioner education module 235 generates a score for the machine learning model comprising an error term based on the label applied to the training example and the predicted likelihood of the medical practitioner in the training example accessing the educational content item in the training example (or a predicted likelihood of the medical practitioner in the training example providing positive feedback for the educational content item included in the training example). The error term, and accordingly the score, is larger when a difference between the label applied to the training example and the predicted likelihood of the medical practitioner in the training example accessing the educational content item in the training example (or the predicted likelihood of the medical practitioner in the training example providing positive feedback for the educational content item included in the training example) is larger and is smaller when the difference between label applied to the training example and the predicted likelihood of the medical practitioner in the training example accessing the educational content item in the training example (or the predicted likelihood of the medical practitioner in the training example providing positive feedback for the educational content item included in the training example) is smaller. In various embodiments, the practitioner education module 235 generates the score for the machine learning model applied to a training example using a loss function based on the difference between the label applied to the training example and the predicted likelihood of the medical practitioner in the training example accessing the educational content item in the training example (or the predicted likelihood of the medical practitioner in the training example providing positive feedback for the educational content item included in the training example). Example loss functions include a mean square error function, a mean absolute error function, a hinge loss function, and a cross-entropy loss function.

[0091] The practitioner education module 235 backpropagates the error term to update a set of parameters comprising the machine learning model and stops backpropagation in response to the score, or to a loss function, satisfying one or more criteria. For example, the practitioner education module 235 backpropagates the score for the machine learning model through the layers of the machine learning model to update parameters of the machine learning model until the score has less than a threshold value. For example, the practitioner education module 235 uses gradient descent to update the set of parameters comprising the machine learning model. The practitioner education module 235 stores the trained machine learning model for application to data describing performance of a medical procedure performed by the medical practitioner and to attributes of one or more educational content items. In some embodiments, the practitioner

education module 235 trains and maintains different machine learning models that each use different combinations of attributes of an educational content item and data describing performance of a medical procedure performed by the medical practitioner.

[0092] Alternatively or additionally, one or more machine learning models applied by the practitioner education module 235 to select an educational content item are nearest neighbor models applied to embeddings corresponding to educational content items and to characteristics of the medical practitioner, including data describing performance of a medical procedure performed by the medical practitioner. As further described above, attributes of an educational content item include: a type of medical procedure associated with the reference content item, one or more medical practitioners associated with the reference content item, a location where the medical procedure was performed (e.g., a geographic location, an identifier of a medical facility), a format of the reference content item (e.g., text data, audio data, video data, etc.), feedback about the reference content item from or more medical practitioners (e.g., a rating, an amount of positive feedback received for the reference content item, etc.), or other descriptive information. Example characteristics of a medical practitioner include: an area of specialization of the medical practitioner, types of prior medical procedures performed by the medical practitioner, medical procedures scheduled to be performed by the medical practitioner, a location where the medical practitioner performs medical procedures (e.g., a geographic location, an identifier of a medical facility, etc.), collaborators connected to the medical practitioner via the connection graph, or other descriptive information about the medical practitioner, as well as data further described above describing performance of a medical procedure by the medical practitioner.

[0093] In some embodiments, the practitioner education module 235 applies a nearest neighbor model to an embedding of the medical practitioner that determines a distance (or a measure of similarity) in a latent space between the embedding of the medical practitioner and embeddings for various educational content items. For example, the nearest neighbor model determines a Euclidean distance between the embedding of the medical practitioner and embeddings for educational content items. Based on the distances, the nearest neighbor model ranks educational content items by the distances (or measures of similarity) of their corresponding embeddings to the embedding of the medical practitioner and selects one or more educational content items having a threshold position in the ranking, so the selected one or more educational content items have embeddings nearest to the embedding of the medical practitioner. Alternatively, the nearest neighbor model selects one or more educational content items having less than a threshold distance from the embedding for the medical practitioner. Alternatively, the practitioner education module 235 generates an embedding for a medical procedure performed by the

medical practitioner and selects one or more educational content items based on distances between the embedding for the medical procedure and embeddings for educational content items, as further described above.

[0094] Further, in some embodiments, the practitioner education module 235 generates embeddings for different medical practitioners based on characteristics of the medical practitioners, as further described above. The practitioner education module 235 determines distances between an embedding for a medical practitioner and embeddings for additional medical practitioners. For example, the practitioner education module 235 determines Euclidean distances between the embedding for the medical practitioner and embeddings for multiple additional medical practitioners. Based on the distances (or measure of similarity), the practitioner education module 235 selects a set of additional medical practitioners. For example, the practitioner education module 235 selects additional medical practitioners with embeddings within a threshold distance of the embedding of the medical practitioner. As another example, the practitioner education module 235 ranks additional medical practitioners based on distances between their embeddings and the embedding of the medical practitioner and selects additional medical practitioners having at least a threshold position in the ranking. The practitioner education module 235 selects one or more educational content items presented to one or more of the selected additional medical practitioners for presentation to the medical practitioner. Such embodiments allow the practitioner education module 235 to leverage similarity between various medical practitioners to select educational content items for presentation to the medical practitioner.

[0095] In various embodiments, the practitioner education module 235 determines one or more baseline criteria for educational content items by applying one or more clustering models to one or more attributes of medical cases in which a specific type of medical procedure was performed. Attributes of a medical case include one or more metrics generated for the medical case by the analytics module 230, telemetry data captured during performance of the medical procedure in the medical case, video data captured during performance of the medical procedure in the medical case, or other descriptive information about the medical case. Based on attributes of a medical case, the practitioner education module 235 generates an embedding for the medical case. The practitioner education module 235 applies a clustering model to embeddings for different medical cases in which the specific type of medical procedure was performed to generate different clusters of case where a specific type of medical procedure was performed. Different clusters are represented in a latent space including the embeddings for medical cases by different centroids, with a cluster including medical cases having embeddings within a threshold distance of the cluster's centroid. In some embodiments, the practitioner education module 235

applies a k-means clustering model to embeddings for different medical cases in which the specific type of medical procedure was performed. Using k-means clustering causes a medical case in which the specific type of medical procedure was performed to be included in a cluster based on distances between the embedding for the medical case and centroids for different clusters. The medical case in which the specific type of medical procedure was performed is included in a cluster with a centroid having a minimum distance from the embedding for the medical case. Centroids of clusters are iteratively updated based on embeddings for medical cases in which the specific type of medical procedure was performed included in various clusters until one or more criteria are satisfied. This results in a specific number of clusters, each including medical cases in which the specific type of medical procedure was performed having similar embeddings.

[0096] The practitioner education module 235 may identify baseline criteria based on medical cases included in one or more clusters. For example, a cluster of cases in which the specific type of medical procedure was performed corresponds to positive outcomes for the specific type of medical procedure, while an alternative cluster corresponds to negative outcomes for the specific type of medical procedure. Based on captured telemetry data or video data during performance of the specific type of medical procedure in an additional case, the practitioner education module 235 generates an embedding for the additional case and determines a cluster including the additional case based on the centroids of the clusters and the embedding for the additional case. In response to determining the additional case is included in the alternative cluster corresponding to negative outcomes, the practitioner education module 235 selects one or more educational content items for presentation to the medical practitioner performing the specific type of medical procedure during the additional case. The practitioner education module 235 compares video data or telemetry data captured during performance of the specific type of medical procedure in the additional medical case to video data or telemetry data associated with baseline criteria of educational content items associated with the specific type of medical procedure and selects one or more educational content associated with the specific type of the medical procedure and having baseline criteria specifying video data or telemetry data differing from the video data or telemetry data captured during performance of the specific type of medical procedure by at least a threshold amount.

[0097] Alternatively, the practitioner education module 235 selects an educational content item for a medical case in response to determining the embedding for the medical case is not included in a particular cluster. As an example, the practitioner education module 235 selects an educational content item for a medical case in response to determining an embedding for the medical case is greater than a threshold distance from a centroid of a particular cluster of medical

cases. This may indicate that the medical case has characteristics that deviate at least a threshold amount from characteristics of other medical cases with positive patient outcomes in which the type of medical procedure was performed. As further described above, the practitioner education module 235 may select an educational content item associated with a specific type of medical procedure being performed in the medical case and having baseline criteria including video data or telemetry data differing from the video data or telemetry data captured during performance of the medical procedure in the medical case by at least a threshold amount.

[0098] When generating clusters of medical cases based on corresponding embeddings, the practitioner education module 235 may identify medical cases included in a particular cluster as reference cases for educational content items for a corresponding type of medical procedure. For example, in response to the practitioner education module 235 including a medical case in a specific cluster associated with positive outcomes, the practitioner education module 235 communicates a prompt to a medical practitioner associated with the medical case to generate a reference case based on the medical case. In response to receiving authorization from the medical practitioner to generate the reference case from the medical case, the practitioner education module 235 pseudonymizes patient data in the medical case and stores the pseudonymized patent data, video data captured during performance of the medical procedure, telemetry data captured during performance of the medical procedure, and one or more metrics generated for the medical procedure as an educational content item for the type of the medical procedure. One or more patterns determined from telemetry data or video data, or one or more generated metrics, are stored as baseline criteria associated with the educational content item. This simplifies creation of educational content items for a type of medical procedure by leveraging data captured by the collaborative medical platform 140 during performance of medical procedures to generate educational content items for subsequent reference about the medical procedure.

[0099] In various embodiments, an educational content item selected for a medical practitioner based on performance of a medical procedure by the medical practitioner is presented to the medical practitioner during a postprocedural stage. Presenting an educational content item to a medical practitioner during the postprocedural stage allows review of the educational content item after completion of a medical procedure. The practitioner education module 235 generates one or more interfaces that identify a selected educational content item to a medical practitioner. For example, the practitioner education module 235 includes information identifying a selected educational content item in a practitioner dashboard presented to the medical practitioner, such as a practitioner dashboard further described below in conjunction with FIG. 4. In various embodiments, information identifying a selected educational content item includes a link that,

when selected by the medical practitioner, retrieves the selected educational content item for presentation. Alternatively, the practitioner education module 235 presents information identifying the educational content item in another interface or in another format. For example, the practitioner education module 235 transmits a notification message to a client device 150 of the medical practitioner that includes a link that, when selected by the medical practitioner, retrieves the selected educational content item for presentation.

[0100] The practitioner education module 235 may include a selected educational content item in one or more interfaces presented to the medical practitioner when accessing the collaborative medical platform 140 in various embodiments. For example, the practitioner education module 235 generates an interface including educational content and presents information describing a selected educational content item through the interface, allowing a medical practitioner to select the information describing the selected educational content item to access the selected educational content item. As another example, the practitioner education module 235 includes information identifying a selected educational content item in a medical case page generated by the interface management module 215 for a medical procedure for which the educational content item was selected. For example, a medical case page includes a section including notes or feedback for the medical practitioner about the medical case, with one or more educational content items selected by the practitioner education module 235 included in the section. Further, the interface management module 215 may generate one or more interfaces including recommendations for a medical practitioner based on metrics for the medical practitioner based on medical procedures, with the recommendation interface including one or more educational content items selected by the practitioner education module for the medical practitioner based on data describing performance of one or more medical procedures.

[0101] In some embodiments, the practitioner education module 235 includes a selected educational content item in different interfaces depending on content of the selected educational content item. For example, educational content items describing the use of a piece of medical equipment or of a medical instrument are displayed in a recommendation interface. As another example, educational content items comprising interactive material or audio or video data for presentation to a medical practitioner are presented in a medical case page or in an education interface. However, in other embodiments, the practitioner education module 235 selects an interface for identifying a selected educational content item based on other characteristics of the educational content item.

[0102] Alternatively or additionally, the practitioner education module 235 presents a selected educational content item to a medical practitioner during an intraprocedural stage of a medical procedure. This presents the selected educational content item to the medical practitioner while

the medical practitioner performs the medical procedure. In various embodiments, the practitioner education module 235 transmits a notification identifying the selected educational content item to a piece of medical equipment 160 or to a client device 150 that displays the notification or audibly presents the notification to the medical practitioner. The notification may include specific content from the selected educational content item to simplify access to relevant information from the selected educational content item by the medical practitioner. In various embodiments, the practitioner education module 235 transmits a notification identifying an educational content item to a piece of medical equipment 160 associated with the educational content item. For example, the educational content item includes recommended settings for the piece of medical equipment 160 (e.g., force thresholds, movement thresholds), so transmitting the notification to the piece of medical equipment 160 simplifies identification of the medical equipment 160 relevant to the educational content item. A notification transmitted to a piece of medical equipment 160 may include a link that, when selected by the medical practitioner, causes the piece of medical equipment 160 to execute one or more instructions that modify one or more settings based on the educational content item. Similarly, information identifying an educational content item associated with a piece of medical equipment 160 presented by a client device 150 may include instructions that, when selected, transmit instructions for modifying one or more settings of the piece of medical equipment 160. This simplifies modification of settings of a piece of medical equipment 160 based on a selected educational content item by reducing an amount of interaction by the medical practitioner with the piece of medical equipment 160. Alternatively, the practitioner education module 235 includes information identifying a selected educational content item in an interface presented to the medical practitioner via a client device 150.

[0103] In some embodiments, a medical practitioner authorizes the practitioner education module 235 to automatically modify one or more settings of a piece of medical equipment 160 based on an educational content item selected for the medical practitioner. Such authorization may be specific to a particular medical procedure or limited to one or more specific pieces of medical equipment 160 used during a particular medical procedure. When the medical practitioner authorizes the practitioner education module 235 to automatically modify one or more settings of the piece of medical equipment 160, the practitioner education module 235 transmits a notification including one or more instructions corresponding to a selected educational content item to a piece of medical equipment 160 used in the medical procedure. The piece of medical equipment 160 executes the one or more instructions, modifying one or more settings of the piece of medical equipment 160 based on the selected educational content item. In various embodiments, the piece of medical equipment 160 displays a notification or

otherwise notifies the medical practitioner that one or more settings have been modified or specified based on the selected educational content item. An indication that one or more settings are to be modified based on a selected educational content item may be presented to the medical practitioner by the piece of medical equipment 160 or by a client device 150 to alert the medical practitioner that one or more settings of the piece of medical equipment 160 are being automatically updated and provide the medical practitioner with an option to prevent modification of the one or more settings. Alternatively, the practitioner education module 235 automatically modifies one or more settings of a piece of medical equipment 160 based on an educational content item selected for a medical practitioner, as further described above, unless the medical practitioner indicates the practitioner education module 235 is not authorized to automatically modify one or more settings of a piece of medical equipment 160. This allows different embodiments to have a medical practitioner to opt-in to the practitioner education module 235 automatically modifying one or more settings of a piece of medical equipment 160 or to opt-out of the practitioner education module 235 automatically modifying one or more settings of a piece of medical equipment 160.

[0104] In other embodiments, presenting an educational content item during the intraprocedural stage of a medical case increases a number of interactions needed to modify one or more settings of a piece of medical equipment 160 used during a medical procedure. For example, presenting the educational content item via a piece of medical equipment 160 causes the piece of medical equipment 160 to request additional confirmation inputs from the medical practitioner subsequent to receiving input from the medical practitioner to change a specific setting of the piece of medical equipment 160 to a value deviating from a corresponding value int eh educational content item or to specify a particular value for the specific setting of the piece of medical equipment 160 outside of a range corresponding to the educational content item. As an example, presenting the educational content item to the medical practitioner transmits an instruction to a piece of medical equipment 160 used during the medical procedure that, when executed, causes the piece of medical equipment 160 to display one or more warnings each requesting an input from the medical practitioner when the piece of medical equipment 160 receiving an input from the medical practitioner to a value of a setting of the piece of medical equipment 160 to a value outside of a range included in the educational content item. This increases difficulty of the medical practitioner configuring the piece of medical equipment 160 in a manner that is inconsistent with the selected educational content item to increase a likelihood that values of settings of the piece of medical equipment 160 are consistent with the selected educational item.

[0105] In various embodiments, the practitioner education module 235 also generates one or

more interfaces for a medical practitioner to request an evaluating medical practitioner evaluate the medical practitioner's performance of a medical procedure. The evaluating medical practitioner has a connection to the medical practitioner via the connection graph store 255 in various embodiments. For example, the evaluating medical practitioner collaborated with the medical practitioner in performing the medical procedure. As an example, the evaluating medical practitioner supervised the medical practitioner performing a medical procedure. Alternatively, the evaluating medical practitioner has a connection to the medical procedure in the connection graph store 255.

[0106] Through an evaluation interface generated by the practitioner education module 235, the medial practitioner selects a medical procedure associated with the medical practitioner for evaluation. For example, the practitioner education module 235 presents the evaluation interface to the medical practitioner in response to receiving a request from the medical practitioner for evaluation. In various embodiments, the practitioner education module 235 receives an identifier of a specific medical procedure from the medical practitioner. Alternatively, the practitioner education module 235 receives a search query via the evaluation interface and presents search results including one or more medical procedures associated with the medical practitioner and having attributes that at least partially match the received search query. Subsequently, the medical practitioner selects a presented medical procedure from the search results. An example evaluation interface is further described below in conjunction with FIG. 11.

[0107] For the selected medical procedure, the practitioner education model 235 receives a selection of a framework for evaluating performance of the selected medical procedure by the medical practitioner. In some embodiments, the practitioner education module 235 presents a framework interface identifying a set of frameworks for evaluating performance of a medical procedure and receives a selection of a framework of the set from the medical practitioner via the framework interface. An example framework interface is further described below in conjunction with FIG. 12. Different frameworks may correspond to different actions performed during the medical procedure or to different techniques performed during the medical procedure. A framework may include guidelines or standards for performing different actions or techniques or include criteria for evaluating one or more actions or techniques. Each framework includes one or more categories that each correspond to different skills or techniques for performing a medical procedure. One or more frameworks may be specific to a medical facility in which the medical procedure was performed, while one or more other frameworks may be based on guidelines or criteria specified by a standardization body or by another entity associated with multiple medical facilities. Example techniques or actions evaluated by a framework include: use of one or more pieces of medical equipment 160 (e.g., robotic medical equipment), techniques specific to a type

of surgery, specific techniques for one or more medical procedures, or other actions affecting performance of a medical procedure.

[0108] When selecting a framework, the medical practitioner may also specify one or more evaluation objectives. An evaluation objective specifies one or more specific techniques to be evaluated, identifies specific information to be provided in the evaluation, specifies one or more types of educational content item to receive based on the evaluation, or specifies other information to be received based on the evaluation. Multiple evaluation objectives may be specified in various embodiments. Specifying one or more evaluation objectives allows the medical practitioner to request specific feedback from evaluation of the medical procedure.

[0109] Additionally, the practitioner education module 235 generates an evaluator selection interface for the medical practitioner for the selected medical procedure, an example of which is further described below in conjunction with FIG. 13. The medical practitioner interacts with the evaluator selection interface to identify an evaluating medical practitioner for the medical procedure. The practitioner education module 235 receives an identifier of an evaluating medical practitioner from the medical practitioner, such as through the evaluator selection interface. In various embodiments, the practitioner education module 235 retrieves identifiers of medical practitioners connected to the medical practitioner or connected to the medical procedure via the connection graph store 255 and presents the retrieved identifiers to the medical practitioner through the evaluator selection interface. The medical practitioner selects an identifier of a medical practitioner connected to the medical practitioner or to the medical procedure to select the evaluating medical practitioner via the evaluator selection interface. Alternatively or additionally, the practitioner education module 235 receives one or more search terms via the evaluator selection interface and generates search results including medical practitioners connected to the medical practitioner, or connected to the medical procedure, and having one or more characteristics at least partially matching the search query. The medical practitioner selects an identifier of a medical practitioner from the search results to select the evaluating medical practitioner.

[0110] For evaluating the medical practitioner's performance of the medical procedure, the practitioner education module 235 retrieves stored data describing performance of the medical procedure by the medical practitioner and receives a selection of a segment of the data describing performance of the medical procedure from the medical practitioner. For example, the practitioner education module 235 retrieves video data and associated metadata (including telemetry data) captured during the medical procedure and associated with the medical procedure stored in the video library 250. In various embodiments, the data describing performance of the medical procedure includes captured video data of the medical procedure, telemetry data

captured by one or more sensors (e.g., sensors on one or more pieces of medical equipment 160 used during the medical procedure), or both video data and telemetry data. The segment of the data describing performance of the medical procedure selected by the medical practitioner comprises a portion of data describing performance of the medical practitioner within a specific time interval. For example, the medical practitioner identifies a starting time and an ending time, with the segment of the data describing performance of the medical procedure comprising data describing performance of the medical procedure occurring between the starting time and the ending time. Hence, the segment includes video data of the medical practitioner between the starting time and the ending time or telemetry data of the medical practitioner captured between the starting time and the ending time in various embodiments. In some embodiments, the practitioner education module 235 maintains one or more specific time intervals, and the medical practitioner selects a starting time and the practitioner education module 235 determines the ending time by incrementing the starting time by a specific time interval to select the segment of the data describing performance of the medical procedure. The practitioner education module 235 may maintain a single specific time interval in some embodiments. Alternatively, the practitioner education module 235 maintains multiple specific time intervals and receives a selection of a specific time interval by the medical practitioner when selecting the segment of the data describing performance of the medical procedure. In various embodiments, the practitioner education module 235 generates a segment selection interface, further described below in conjunction with FIG. 14, through which the medical practitioner selects one or more segments of data describing performance of the medical procedure.

[0111] Alternatively, the practitioner education module 235 may apply one or more models to data describing performance of the medical procedure to automatically generate segments of the data describing performance of the medical procedure and store the generated segments in association with the medical practitioner. Each segment includes a portion of data describing performance of the medical procedure between a starting time and an ending time. The medical practitioner selects a specific segment from the stored segments in various embodiments.

[0112] The medical practitioner may select multiple segments of the data describing performance of the medical procedure in some embodiments. Further, the medical practitioner may select different frameworks for evaluating different segments of the data describing performance of the medical procedure in some embodiments, allowing for evaluation of different skills or techniques in different segments of the data describing performance of the medical procedure against different standards or criteria. In some embodiments, the medical practitioner selects a segment of the data describing performance of the medical procedure then selects a framework for evaluating the segment.

[0113] In some embodiments, the medical practitioner provides self-evaluation data for one or more categories in the selected framework. For example, the self-evaluation data comprises a self-specified value for each category included in the selected framework the practitioner education module 235 receives from the medical practitioner. A self-specified value for a category is selected from a set of values in various embodiments. Providing self-evaluation data for categories in the selected framework allows the medical practitioner to compare the medical practitioner's self-evaluation of performance in different categories of the framework to evaluation values for the categories determined by the selected evaluating medical practitioner. Such a comparison allows the medical practitioner to more accurately assess the medical practitioner's proficiency with various techniques or skills relative to the selected standard.

[0114] The practitioner education module 235 generates an evaluation message including: information about the selected medical procedure, information identifying the medical practitioner, the selected framework, and the selected one or more segments of the data describing performance of the medical procedure (as well as the self-evaluation data in some embodiments). In various embodiments, the practitioner education module 235 transmits the evaluation message to the evaluating medical practitioner, who reviews the data describing performance of the medical procedure in the selected one or more segments and generates evaluation results for the medical practitioner by comparing the data describing performance of the medical procedure against criteria in the selected framework. The evaluation results include an evaluation value assigned to each category of the selected framework by the evaluating medical practitioner based on review of the data describing performance of the medical procedure in the one or more segments.

[0115] Additionally, the evaluation results may include comments from the evaluation medical practitioner associated with one or more portions of the data describing performance of the medical procedure within a selected segment. The evaluating medical practitioner may associate different comments with different portions of the data describing performance of the medical procedure in a selected segment. For example, a comment is associated with a specific time in the time interval comprising the segment of the data describing performance of the medical procedure. As an example, a comment is associated with a specific time in the segment of video data describing performance of the medical procedure. In another example, a comment is associated with a specific time within the segment of telemetry data describing performance of the medical procedure. Including one or more comments associated with specific times in a selected segment allows the evaluating medical practitioner to provide feedback to the medical practitioner for specific times during the selected segment of data describing performance of the medical procedure for the medical practitioner to further review.

[0116] In various embodiments, the practitioner education module 235 generates an evaluation result interface in response to receiving evaluation results from the evaluating medical practitioner. An example evaluation result interface is further described below in conjunction with FIG 15. The evaluation result interface identifies the evaluating medical practitioner, the medical practitioner, and a type of the medical procedure performed by the medical practitioner. Additionally, the evaluation result interface includes evaluation values for different categories in the selected framework. In various embodiments, the evaluation result interface includes data describing performance of the medical procedure corresponding to the selected section and may include comments associated with one or more specific times in the section of data describing performance of the medical procedure received from the evaluating medical practitioner. For example, the evaluation result interface includes video data corresponding to the selected segment and may include one or more comments associated with one or more specific times in the video data corresponding to the selected segment. In some embodiments, the practitioner education module 235 displays a specific portion of the data describing performance of the medical procedure during the selected segment in response to receiving a selection of a comment from the medical practitioner. The comment may be displayed proximate to the corresponding specific portion of the data describing performance of the medical procedure during the selected segment in some embodiments to simplify review of the relevant portion of the data describing performance of the medical procedure while reviewing the comment.

[0117] In various embodiments, the practitioner education module 235 selects one or more educational content items for presentation to the medical practitioner based on one or more evaluation values for one or more categories of the selected framework in the evaluation results. For example, in response to the practitioner education module 235 determining an evaluation value for a category of the selected framework is less than a threshold value, the practitioner education module 235 selects an educational content item associated with a type of the medical procedure and having a baseline criterion specifying a value for the category of the selected framework that equals or exceeds the threshold value. As another example, the practitioner education module 235 selects an educational content item associated with the type of the medical procedure and having a baseline criterion specifying a particular value for a category of the selected framework that is at least a threshold amount greater than the evaluation value of the category in the evaluation results. The practitioner education module 235 may select an educational content item associated with each category of the selected framework having an evaluation value less than a value for corresponding category of the selected framework specified as a baseline criterion in an educational content item associated with the type of the medical procedure. Hence, evaluation results from the evaluating medical practitioner may be

leveraged by the practitioner education module 235 to select one or more educational content items for presentation to the medical practitioner, as further described above.

[0118] Additionally or alternatively, the practitioner education module 235 uses evaluation results obtained for various medical procedures having a specific type to train an evaluation model to generate predicted evaluation values for one or more categories based on data describing performance of a medical procedures. In various embodiments, the practitioner education module 235 generates training examples from evaluation results received for medical procedures. Each training example includes a training segment of data describing performance of a segment of a training medical procedure having a type and a training framework; each training example also has one or more labels identifying a category of the training framework and an evaluation score for the training category of the training framework. In some embodiments, a training example includes multiple labels each including a pair of an identifier of a category of the training framework and a corresponding evaluation score. Alternatively, each training example includes a single label including an identifier of a category of the framework and an evaluation score for the category. In various embodiments, the practitioner education module 235 obtains training examples based on evaluation values provided by one or more evaluating medical practitioners when evaluating segments of medical procedures for medical practitioners, as further described above.

[0119] The practitioner education module 235 trains the evaluation model by applying the evaluation model to a set of training examples. Applying the evaluation model to a training example generates a predicted evaluation value for one or more categories of the training framework included in the training example based on the training segment of data describing performance of the training medical procedure in the training example. For each training example to which the practitioner education module 235 applies the evaluation model, the practitioner education module 235 generates a score for the evaluation model comprising an error term based on the label applied to the training example and a predicted evaluation value (or based on one or more error terms based on labels corresponding to different categories of the training framework included in the training example and predicted evaluation values for corresponding categories of the training framework included in the training example). The error term, and accordingly the score, is larger when a difference between the label applied to the training example and the predicted evaluation value for the training example is larger and is smaller when the difference between label applied to the training example and the predicted evaluation value for the training example is smaller. In various embodiments, the practitioner education module 235 generates the score for the evaluation model applied to a training example using a loss function based on the difference between the label applied to the training example

and the predicted evaluation value for the training example. Example loss functions include a mean square error function, a mean absolute error function, a hinge loss function, and a cross-entropy loss function.

[0120] The practitioner education module 235 backpropagates the error term to update a set of parameters comprising the evaluation model and stops backpropagation in response to the score, or to a loss function, satisfying one or more criteria. For example, the practitioner education module 235 backpropagates the score for the evaluation model through layers of the evaluation model to update parameters comprising the machine learning model until the score has less than a threshold value. For example, the practitioner education module 235 uses gradient descent to update the set of parameters comprising the evaluation model. The practitioner education module 235 stores the trained evaluation model for application to data describing performance of a segment of a medical procedure performed by a medical practitioner and to a framework to generate predicted evaluation scores for one or more categories in the framework. In some embodiments, the practitioner education module 235 trains and maintains different evaluation models for each category in a framework, with category-specific evaluation models generating predicted evaluation values for different categories in a framework.

[0121] The practitioner education module 235 selects one or more educational content items for presentation to a medical practitioner based on predicted evaluation values for categories of a framework in some embodiments. For example, in response to receiving an evaluation request from the medical practitioner and a selection of a framework, the practitioner education module 235 applies one or more evaluation models, trained as further described above, to a segment of data describing performance of the medical procedure by the medical practitioner and to the selected framework, generating predicted evaluation values for one or more categories of the selected framework. In some embodiments, the practitioner education module 235 applies a different evaluation model to a segment of the data describing performance of the medical procedure by the medical practitioner and to the selected framework to generate predicted evaluation values for different categories of the selected framework. Similarly, the practitioner education module 235 may apply different evaluation models corresponding to different frameworks to different segments of the data describing performance of the medical procedure. This allows different frameworks to be used to evaluate different segments of data describing performance of the medical procedure. Based on differences between a predicted evaluation value for a category and a value for the category included as a baseline criterion in one or more educational content items, the practitioner education module 235 may select one or more educational content items for presentation to the medical practitioner, as further described above. Hence, the practitioner education module 235 may leverage one or more trained evaluation

models to generate predicted evaluation scores for the medical practitioner based on a framework and a segment of data describing performance of a medical procedure then use one or more additional machine-learned models to select educational content items for presentation to the medical practitioner.

[0122] When selecting reference content items for a medical practitioner based on evaluation values for categories of a framework or based on predicted evaluation values for categories of a framework, the practitioner education module 235 may select educational content items based on evaluation values or predicted evaluation values determined for individual medical procedures performed by the medical practitioner, as further described above. Alternatively or additionally, the practitioner education module 235 determines an aggregate value for a category of a framework based on evaluation values or predicted evaluation values determined for multiple medical procedures having a common type and performed by the medical practitioner. For example, an aggregate value for a category of a framework is an average of evaluation values or predicted evaluation values determined for the medical practitioner for performance of multiple medical procedures having the common type. As another example, an aggregate value for a category of a framework is median of evaluation values or predicted evaluation values determined for the medical practitioner for performance of multiple medical procedures having the common type. The practitioner education module 235 selects one or more educational content items for the medical practitioner by comparing the aggregate value for the category to baseline criterion specifying a value for the category in one or more educational content items, as further described above. Alternatively or additionally, the practitioner education module 235 selects one or more educational content items for the medical practitioner based on a change in evaluation values or predicted evaluation values for a category of a framework for the medical practitioner over time. For example, in response to determining evaluation values or predicted evaluation values for the medical practitioner in a category of a framework when performing medical procedures having a specific type decrease at least a threshold amount during a specific duration, the practitioner education module 235 selects an educational content item associated with the specific type of medical procedure and the category for presentation to the medical practitioner.

[0123] The presentation module 240 leverages stored information associated with a completed medical procedure to facilitate generation of presentations for education, research, training, or other purposes. Presentations may be in the form of slide decks, posters, videos, animations, or other multimedia content. Presentations may incorporate various multimedia (e.g., video, images, three-dimensional models, and associated metadata), patient record data, medical equipment telemetry data, information from content feeds, analytics, or other information

generated and/or stored by the collaborative medical platform 140.

[0124] In an embodiment, the presentation module 240 may maintain one or more presentation templates for generating presentations. The template may include pre-formatted content with various information fields that may be automatically populated from a set of records. For example, a practitioner wanting to prepare a presentation relating to a set of recently performed procedures may specify the set of procedures to include in the presentation, and the presentation module 240 may automatically populate the presentation based on the data stored in association with those procedures. pages, with each page associated with one or more types of data about the completed medical procedure. In some embodiments, the presentation module 240 may apply one or more trained machine learned models to automatically generate and/or recommend presentation content that may be of interest to a medical practitioner. In further embodiments, the presentation module 240 may intelligently automatically de-identify patient data included in the presentations.

[0125] The presentation module 240 may furthermore include various editing tools for creating, viewing, and editing presentations. For example, the editing tools may enable editing of text, video, images, animations, three-dimensional models, or other content for including in a presentation.

[0126] In an embodiment, presentations may be presented through a presentation module 240 directly without data associated with the presentation being exported externally to the collaborative medical platform 140. For example, the presentation module 240 may enable live streamlining of a presentation during a telepresence session to a set of invited attendees. The invited attendees may be limited to users 155 of the collaborative medical platform 140 or may include outside attendees that may gain access via an external link. Sharing presentations in this manner enables practitioners to maintain data privacy and compliance and avoid issues that may arise when externally exporting medical data.

[0127] The application integration module 245 manages integration of applications with the collaborative medical platform 140. Applications may be utilized to add additional optional functionality to the collaborative medical platform 140. For example, applications may enable integration with a specific EHR system, scheduling system, or other existing medical system. Applications may furthermore enable users to selectively add specific functionality beyond the core features of the collaborative medical platform 140. The application integration module 245 may allow third parties to create applications that interface with the collaborative medical platform 140 and make these applications available to add.

[0128] The application integration module 245 may maintain a catalog of applications capable

of interfacing with the collaborative medical platform 140 and may provide interfaces to enable users 155 to selectively add applications for integration. In various embodiments, applications identified by the application integration module 245 have been authorized or approved for installation by an administrator of the collaborative medical platform 140, allowing regulation of the applications capable of executing on the collaborative medical platform 140.

[0129] Additionally, the application integration module 245 may include one or more application programming interfaces (API) for an application installed through the application integration module 245. An API for an application provides functionality for exchanging data between the application and one or more components of the collaborative medical platform 140, simplifying data exchange between the application and other portions of the collaborative medical platform 140.

[0130] The video library 250 stores videos of various medical procedures, training presentations, simulations, or other medical videos and metadata associated with the video. Examples of metadata associated with video of a medical procedure may include telemetry data of one or more medical instruments received in conjunction with the video, comments or annotations received from one or more medical practitioners through a surgical interface during the medical procedure included in the video, segmentation data that divides the video into temporal segments relating to different step of a procedure, profile information (e.g., age, body mass index, gender, etc.), associated with the patient in the video, or other information supplementing the video. Various reference content items including video data may be stored in the video library 250 for retrieval by the practitioner education module 235 in various embodiments.

[0131] The video library 250 may store videos in an indexed database that indexes videos based on various metadata. The video library 250 can then be browsed or searched via a video library interface to identify videos of relevance. The metadata associated with videos may include permissions stored in the connection graph store 255 that controls which users 155 have access to different videos. For example, a video in the video library 250 may be accessible only to users 155 that the video has been expressly shared with or that otherwise has viewing permissions for the video.

[0132] The connection graph store 255 comprises a database that stores information describing connections between entities or other objects (e.g., videos or other multimedia) managed by the collaborative medical platform 140. For example, as described above, the connection graph store 255 stores connections between users 155, connections between users 155 and procedures, connections between users 155 and multimedia content or other objects, or other connections between data entities of the collaborative medical platform 140.

[0133] The user profile store 260 stores profile data for users 155 of the collaborative medical platform 140. A user profile for a medical practitioner includes descriptive information such as a name of the medical practitioner, contact information for the medical practitioner, credentials or certifications of the medical practitioner, biographical information for the medical practitioner, types of medical procedures capable of being performed by the medical practitioner, medical facilities affiliated with the medical practitioner, operating room preferences (such as patient positioning, equipment setup, preferred instrumentation, typical procedure step order, etc.), equipment configuration preferences (e.g., ergonomic settings for a robot console), or other information describing the medical practitioner. Aspects of the user profile could be inferred using machine learning techniques. For example, a practitioner's preferred instrumentation or step order may be inferred from application of a machine learning model trained to infer such preferences based on observed historical data. Additionally, a user profile for a medical practitioner includes medical procedures performed by or to be performed by the medical practitioner, as well as information describing the medical procedures. For example, the user profile identifies different types of medical procedures to be performed by, or performed by, the medical practitioner, and may include characteristics for each medical procedure (e.g., a length of time to complete the medical procedure, a number of times the medical practitioner performed a type of medical procedure matching the medical procedure, etc.). Further, one or more of the metrics determined by the analytics module 230 for the medical practitioner, as further described above, may be included in the user profile for the medical practitioner.

[0134] The patient data store 265 includes a patient profile for each patient associated with medical cases. A patient profile includes characteristics of a corresponding patient, which may be obtained from an electronic health record for the patient or may be provided via input from a medical practitioner. Characteristics of a patient include demographic information about the patient, medical conditions of the patient, medical procedures previously performed by the patient, allergies of the patient, contact information for the patient, current or prior prescriptions for the patient or other medically relevant information about the patient. A patient identifier is associated with a patient profile to uniquely identify the patient profile.

[0135] All of the data stored to the collaborative medical platform 140 (or otherwise made available through the collaborative medical platform 140) may be stored, presented, and in some cases restricted in a manner that ensures compliance with various data privacy and protection regulations.

[0136] FIGs. 3A-3B illustrate an example practitioner dashboard 300. FIG. 3A shows an upper portion of the dashboard 300 while FIG. 3B shows a lower portion of the dashboard 300 (which may be continuously scrollable). The practitioner dashboard 300 may operate as a home landing

page for a medical practitioner upon logging into the collaborative medical platform 140. The practitioner dashboard 300 may include various content sections, at least some of which may be specifically targeted to the practitioner. A search bar 305 enables input of text-based search queries for searching content available in the collaborative medical platform 140 (e.g., case pages, other user pages, videos, presentations, etc.). In response to inputting a search query, a list of results may be displayed with links to content matching the search query. A video promotion section 310 shows a video recently added by the practitioner with user interface tools to enable the practitioner to promote the video by sharing it with other users, create a highlight reel, or view various statistical information about the video. An achievement section 315 presents an achievement relating to use of the collaborative medical platform 140. In this example, the achievement section 315 highlights that the user has recently reached 100 videos and provides links to view the user's videos and access a video library. Other examples of achievements in the achievement section 315 could relate to number of cases managed, time using the platform 140, number of connections, count of frequency of interactions, or other usage achievements. The video library 320 includes video thumbnails, video tags, or other links to enable browsing of videos selected as potentially relevant to the medical practitioner. For example, relevant videos may be selected that relate to past or upcoming procedures associated with the medical practitioner, based on a history of videos viewed by the medical practitioner, based on a practice area or other profile information for the medical practitioner, or other factors. The webinar promotion section 325 includes a promotional banner for an upcoming webinar that will be viewable within the collaborative medical platform 140. The webinar may be identified as being of potential interest to the medical practitioner based on, for example, the subject matter of the webinar, the host of the webinar, or other factors. The shared cases section 330 provides summary information and links to case pages that have been shared with the medical practitioner. Examples of case pages are described in further detail below. The analytics summary 335 includes example analytics associated with the medical practitioner's usage of the collaborative medical platform 140, procedures performed by the medical practitioner, or other analytics data derived from information stored in the collaborative medical platform 140. The analytical data may be presented in one or more visual representations such as a graph or chart. The feedback section 340 provides links to enable the medical practitioner to send feedback to an administrator of the collaborative medical platform 140.

[0137] FIGs. 3A-3B illustrate just one example of a practitioner dashboard 300. The types of content presented in the practitioner dashboard 300 may be different for different practitioners and/or may dynamically change over time for the same medical practitioner. Some of the sections may be fixed and always appear upon accessing the dashboard 300 (e.g., the search bar

305, video library 320, shared cases 330, analytics 335, and feedback sections 340), while other sections (e.g., video promotion 310, achievement 315, webinar promotion 325) may be dynamically inserted only in certain contexts. For example, webinar promotions 325 may be presented only when an upcoming webinar deemed to be of sufficient interest is upcoming. Achievements 315 may similarly be displayed only when a relevant achievement has recently been achieved. Furthermore, the dashboard 300 could be customized by the user to display desired sections in a configured order. The various sections 305, 310, 315, 320, 325, 330, 335, 340 when present, may furthermore be presented in different order in different contexts.

[0138] FIG. 4 shows an alternative embodiment of a practitioner dashboard 400. In the example shown by FIG. 4, the practitioner dashboard 400 includes an educational content item section 405 including information identifying an educational content item selected for a medical practitioner based on a previously performed medical procedure. The practitioner education module 235 selects the identified educational content item based on stored baseline criteria for educational content items associated a type of the previously performed medical procedure and captured data describing performance of the previously performed medical procedure, as further described above in conjunction with FIG. 2. In various embodiments, the educational content item section 405 identifies one or more reasons why the identified educational content item is of potential interest to the medical practitioner. In the example of FIG. 4, the educational content item section 405 indicates that the identified educational content item includes suggested parameters or settings for a piece of medical equipment 160 (e.g., a robotic arm) used in the previously performed medical procedure. The educational content item section 405 in the example of FIG. 4 includes a link 410 that, when selected by the medical practitioner retrieves the educational content item for presentation to the medical practitioner via a client device 150 of the medical practitioner.

[0139] For purposes of illustration, FIG. 4 shows an example practitioner dashboard 400 where the educational content item section 405 is displayed proximate to a search bar 305. For example, the educational content item section 405 is displayed in a position of the practitioner dashboard 400 below the search bar 305, so the educational content item section 405 is prominently displayed in the practitioner dashboard 400 to increase a likelihood of the medical practitioner selecting the link 410 to the identified educational content item. However, in other embodiments, the practitioner dashboard 400 displays the educational content item section 405 in a different position relative to other sections. Similarly, while FIG. 4 shows an example where the achievement section 315 and the video library section 320 are displayed in conjunction with the educational content item section 405, in other embodiments, different or additional sections are displayed by the practitioner dashboard 400 in conjunction with the suggested

reference content item section 405.

[0140] In various embodiments, the educational content item section 405 is dynamically inserted into the practitioner dashboard 400 in certain contexts and is not included in the practitioner dashboard 400 in other contexts. For example, the practitioner dashboard 400 displays the educational content item section 405 after the medical practitioner has completed a medical procedure. In an example, the practitioner dashboard 400 displays the educational content item section 405 starting a specific amount of time after the medical practitioner completed a medical procedure, but does not display the educational content section 405 before the specific amount of time lapses after completion of the medical procedure. The practitioner dashboard 400 displays the educational content item section 405 for a particular time interval after the medical practitioner completed the medical procedure in various embodiments.

[0141] While FIG. 4 shows an example where the educational content item section 405 identifies a single reference content item, in other embodiments, the educational content item section 405 displays multiple reference content items selected for the medical practitioner. For example, the educational content item section 405 is a carousel content item having multiple slides, with each slide including information identifying a different selected educational content item and including a link to a different selected educational content item. In response to the medical practitioner performing a specific interaction with the educational content item section 405, the educational content item section 405 is updated to display a different slide including information identifying a different selected educational content item. For example, the educational item section 405 displays an alternative slide including information identifying a different selected educational content item in response to the medical practitioner performing a swiping gesture along an axis perpendicular to an axis including the search bar 305, the educational content item section 405, the achievement section 315, and the video library section 320. This allows a single section of the practitioner dashboard 400 to identify multiple educational content items to the medical practitioner.

[0142] In some embodiments, the collaborative medical platform 140 generates one or more education interfaces, such as an education dashboard. An education interface may additionally or alternatively display one or more suggested educational content items to a medical practitioner, providing an additional way for the medical practitioner to access the suggested educational content items. The practitioner dashboard 400 may include an interface element that, when selected by the medical practitioner, causes display of the education interface. The education interface may display information identifying multiple suggested educational content items in some embodiments, allowing the medical practitioner to more easily access a wider range of suggested educational content items.

[0143] FIG. 5 shows an example embodiment of a case sharing interface 500 for sharing a case with one or more contributors. Adding a contributor to a case may generate a connection between the contributor and the case and between the contributor and the case owner. The case sharing interface 500 includes a selection element 505 for receiving identifying information to identify a desired contributor. For example, the selection element 505 may receive an email address, name, a username, or another identifier of a medical practitioner or other requested contributor. In some embodiments, upon selecting identifying information for a desired contributor, the case sharing interface 500 may display all or a portion of profile data for the requested collaborator to enable the requestor to confirm if the matched profile data is the intended collaborator. The case sharing interface 500 then enables the requestor to confirm or decline selection of a collaborator and interact with a permission selection element 520 to set a desired permission level for the requested collaborator. Here, the permission level may place limits on an invited collaborator's access to data about the case and/or may limit actions the collaborator is permitted to perform in association with the case. In an example embodiment, the permission level may be selected between a "collaborator" level 525A and a "delegate" level 525B.

[0144] In response to receiving inputs to select a requested collaborator and set a desired permission level (via the permission selection element 520), the case sharing interface 500 may send an invitation to the requested contributor (e.g., via an email, text message, phone call, portal message, or other communication mechanism) to enable the requested collaborator to accept or decline the request. If the request is accepted, the case sharing interface 500 may add the identifier or other information for the new collaborator to a connected medical practitioner listing 510 that lists the contributors added to the case. For example, the illustrated example shows a connected medical practitioner listing 510 that includes the case owner 515 and three additional contributors that have been added to the case.

[0145] The case sharing interface 500 may furthermore enable the case owner to change permission levels of existing contributors in the connected medical practitioner listing 510. Furthermore, the case sharing interface 500 may include removal elements 530 associated with each contributor in the connected medical practitioner listing 510 that enables removal of a contributor from the case. Selection of a removal element 530 may remove the stored connection in between the practitioner and the case, such that the practitioner no longer has access to the case.

[0146] FIG. 6 is an example embodiment of a case dashboard 600 for a medical practitioner. The case dashboard 600 enables access to cases owned by the medical practitioner and cases shared with the medical practitioner by other users 155 as indicated in the case summary 610. In

this example, the case dashboard 600 is organized as a set of case cards 605 that each graphically show a summary of a case. Selecting a case card 605 links to a case page 400 for the case. In alternative embodiments, the dashboard 600 may be presented in a list view or other view without necessarily presenting case cards 605 in the visual form shown in FIG. 6.

[0147] FIG. 7 shows an example of a telepresence interface 700 associated with a telepresence session that may take place during an actual procedure or during a simulated procedure. Alternatively, the telepresence session may be utilized for live planning purposes without necessarily performing or simulating a procedure. In this example, the telepresence interface 700 displays a three-dimensional model of a target anatomy 705 associated with the procedure. The model may include annotated comments that may be obtained during the telepresence session or that were added in a preprocedural stage. Alternatively, the telepresence interface 700 may include a view of real-time video or images associated with an ongoing procedure. In an embodiment, each contributor may be able to switch between different relevant views such as real-time video or images, three-dimensional models, preprocedural images, or other relevant multimedia.

[0148] The telepresence interface 700 may furthermore include a telepresence content feed 715 for sending and receiving real-time messages between contributors. For example, a telepresence content feed 715 allows users to post messages and/or view messages from other participants. The messages may include text, media content (e.g., images, video, animations, etc.), or links to various media content or other resources (e.g., research articles). The telepresence interface 700 may furthermore enable participants to provide annotations on the target anatomy (presented in the form of an image, video, or model). For example, a participant may pin a comment to a specific location in the depicted anatomy, as may be indicated by an identifier 710.

[0149] Additionally, the telepresence interface 700 may display statistics 720 or other analytics that may be relevant to the procedure. The statistics 720 maybe include estimated or modeled values or metrics relating to the anatomy based on various sensed data from the medical equipment 160. The telepresence interface 700 may dynamically update the statistics 720 over time during the procedure.

[0150] FIG. 8 is another example of a telepresence interface 800 associated with a telepresence session. In this example, the telepresence interface 800 shows a live video of a procedure being performed together with a set of annotation tools 810 that enables a remote contributor to add annotation 805 overlaid on the video. The telepresence interface 800 also includes a set of alternative views 815 the contributor can switch between during the telepresence session. These alternative views 815 may include one or more different camera views (e.g., a view of the

medical environment), one or more three-dimensional models (e.g., as shown in FIG. 7), views of preprocedural images, or other multimedia associated with the case. In various embodiments, telepresence interfaces, such as shown in FIGS. 7 or 8, are stored for a medical case and may be subsequently presented to other medical practitioners if a medical practitioner associated with the case authorizes generation of a reference case based on the medical case, as further described above in conjunction with FIG. 2.

[0151] In the example of FIG. 8, the telepresence interface 800 also displays an educational content item 820 to a medical practitioner, such as the medical practitioner performing the medical procedure. The educational content item 820 is dynamically selected by the telepresence interface 800 in various embodiments based on captured video data or telemetry data during the medical procedure. The telepresence interface 800 includes information describing the educational content item 820 or extracted from the educational content item 820, allowing the medical practitioner to discern content from the educational content item 820 via the telepresence interface 800. In various embodiments, the telepresence interface 800 limits presentation of the educational content item 820 to certain time intervals. For example, the telepresence interface 800 displays the educational content item 820 in response to the collaborative medical platform 140 determining that video data or telemetry data captured during performance of the medical procedure deviates by at least a threshold amount from baseline criteria associated with the educational content item 820. When captured video data or telemetry data does not deviate by at least the threshold amount from the corresponding baseline criteria for the educational content item 820, the telepresence interface 800 does not present the educational content item 820. For example, a client device 150 displaying the telepresence interface 800 receives a presentation instruction to present the educational content item 820 along with the educational content item 820 from the collaborative medical platform 140 and subsequently receives an alternative instruction to stop presenting the educational content item 820 from the collaborative medical platform 140. The alternative instruction may be received in response to the collaborative medical platform 140 determining video data or telemetry data received during performance of the medical procedure satisfies baseline criteria associated with the educational content item 820 or in response to determining video data or telemetry data no longer identifies a pattern corresponding to a baseline criterion associated with the educational content item 820.

[0152] To simplify incorporation of information from the educational content item 820 into the medical procedure, the telepresence interface 800 presents a modification instruction 825 in association with the educational content item 820. The modification instruction 825 includes an identifier of a piece of medical equipment 160 and values of one or more settings for the piece of

medical equipment 160. In response to the medical practitioner selecting the modification instruction 825 via the telepresence interface 800, the collaborative medical platform 140 receives a request identifying the educational content item 820 and the piece of medical equipment 160. In response to receiving the request, the collaborative medical platform 140 transmits an instruction to the identified piece of medical equipment 160 to modify values of one or more settings to values retrieved from the educational content item 820 and included in the instruction transmitted to the piece of medical equipment 160. In various embodiments, the collaborative medical platform 140 determines the identifier of the piece of medical equipment 160 based on an identifier included in telemetry data received by the collaborative medical platform 140 or based on identifying information included in received video data of the medical procedure. This simplifies modification of one or more settings of the piece of medical equipment based on the educational content item 820 via interaction with the telepresence interface 800 rather than by manually entering values for settings identified by the educational content item to the piece of medical equipment 160.

[0153] FIG. 9 is an example embodiment of an analytics dashboard 900 for a medical practitioner. In this example, the analytics dashboard 900 displays a summary of cases managed by the medical practitioner includes, for example, a total number of cases, a number of cases in the current month, a number of cases in the current week, and a distribution of types of cases the practitioner has performed. In the example of FIG. 9, the analytics dashboard 900 also displays an educational content item section 905 to the medical practitioner. The educational content item section 905 includes information identifying an educational content item the collaborative medical platform 140 selected for the medical practitioner based on data describing performance of a medical procedure by the medical practitioner, as further described above in conjunction with FIG. 2. The educational content item section 905 includes a link that, when accessed, retrieves the educational content item from the collaborative medical platform 140 or from a third-party server 170 for presentation in various embodiments. The educational content item section 905 may identify an educational content item selected based on a medical procedure most recently completed by the medical practitioner in some embodiments. Alternatively, the analytics dashboard 900 includes multiple educational content item sections 905, with each educational content item section including an educational content item selected for a medical procedure previously performed by the medical practitioner, simplifying access to different educational content items relevant to various medical procedures performed by the medical practitioner.

[0154] FIG. 10 is an example embodiment of case video interface dashboard 1000 for viewing a case video. Case videos may be captured during a telepresence session or may be similarly

captured during a procedure without a live streamed telepresence session. The case video interface 1000 includes a video interface that shows one or more views of a video associated with a medical procedure. The video interface 1000 may include multiple captured views, which may be from cameras in the medical environment, cameras inserted into the anatomy (e.g., endoscopy cameras), or other cameras. Captured views may furthermore include three-dimensional models, preprocedural images, procedure planning documents, or other visual information. The video may be segmented (manually or automatically using video processing and content recognition techniques) to divide the video into segments associated with different steps of the procedure. The video may include annotations provided by a medical practitioner during a telepresence session or in a postprocedural review. A content feed 1010 may be presented in association with a video to enable users 155 to post comments, links, media, or other content in association with the presentation. A reference content item, such as a reference case, may display video and other information (e.g., a content feed 1010) of a medical procedure to a medical practitioner using the video interface 1000 described in conjunction with FIG. 10.

[0155] FIG. 11 is an example evaluation interface 1100 for a medical practitioner to request evaluation of at least a portion of a medical procedure performed by the medical practitioner. In various embodiments, the collaborative medical platform 140 displays the evaluation interface 1100 in response to receiving a request from a client device 150 of a medical practitioner for evaluation of a medical procedure by an evaluating medical practitioner. The example evaluation interface 1100 shown in FIG. 11 includes a search element 1105 configured to receive one or more search terms from the medical practitioner. Based on the received search terms, the collaborative medical platform 140 identifies one or more medical procedures associated with the medical practitioner and having one or more characteristics that at least partially satisfy the received search terms. The evaluation interface 1100 displays medical procedure identifiers 1110 of the one or more medical procedures identified in response to the received search terms. For example, the collaborative medical platform 140 retrieves medical procedures having a connection to the medical practitioner in the connection graph store 255 and identifies one or more of the retrieved medical procedures having characteristics that at least partially match search terms received via the search element 1105 in the evaluation interface 1100. The medical practitioner selects a medical procedure identifier 1110 corresponding to the medical procedure for evaluation.

[0156] FIG. 12 is an example framework interface 1200 for a medical practitioner to select a framework for evaluating at least a portion of a medical procedure performed by the medical practitioner. In various embodiments, the collaborative medical platform 140 presents the framework interface 1200 to the medical practitioner after receiving a selection of a medical

procedure from the medical practitioner. The framework interface 1200 presents a set 1205 of frameworks for evaluating the medical procedure. Different frameworks of the set 1205 may correspond to different types of actions performed during the medical procedure or to different techniques performed during the medical procedure. A framework may include guidelines or standards for performing different types of actions or techniques or may include criteria for evaluating one or more actions or techniques. Each framework includes categories corresponding to different skills or techniques applicable to performing a medical procedure. Different frameworks may specify different criteria for evaluating a category, or different frameworks may include different categories. One or more frameworks may be specific to a medical facility in which the medical procedure was performed, while one or more other frameworks may be based on guidelines or criteria specified by a standardization body or other entity associated with multiple medical facilities. The medical practitioner selects a framework of the set 1205 via an interaction with the framework interface 1200. For example, the medical practitioner performs a specific interaction with information identifying a framework of the set 1205 to select the framework for evaluating the medical procedure.

[0157] In various embodiments, the framework interface 1200 also includes an evaluation objective element 1210. An evaluation objective identifies one or more specific techniques to be evaluated by an evaluating medical practitioner, identifies specific information to be provided in the evaluation, identifies one or more types of educational content items to receive based on the evaluation, or identifies other information to be received based on the evaluation. Multiple evaluation objectives may be specified in various embodiments. The evaluation objective element 1210 receives input from the medical practitioner describing or otherwise identifying an evaluation objective. For example, the evaluation objective element 1210 comprises a text box configured to receive text input describing the evaluation objective from the medical practitioner. As another example the evaluation objective element 1210 includes a set of evaluation objectives and the medical practitioner selects one or more evaluation objectives from the set of evaluation objectives by interacting with the evaluation objective element 1210.

[0158] FIG. 13 is an example evaluator selection interface 1300 for a medical practitioner selecting an evaluating medical practitioner for a medical procedure. In some embodiments, the collaborative medical platform 140 presents the evaluator selection interface 1300 after presenting the evaluation interface 1100 and the framework interface 1200 to the medical practitioner. The evaluator selection interface 1300 includes an evaluator search element 1305 configured to receive a search query from the medical practitioner. Based on the search query, the evaluator selection interface 1300 displays one or more medical practitioner identifiers 1310. Each medical practitioner identifier 1310 corresponds to a medical practitioner having one or

more characteristics that at least partially satisfy the search query. In some embodiments, the medical practitioner identifiers 1310 correspond to medical practitioners having a connection to the medical practitioner, or to the medical procedure, in the connection graph store 225 and having one or more characteristics that at least partially match the search query. The medical practitioner corresponding to a medical practitioner identifier 1310 selected by the medical practitioner via the evaluation interface 1300 is the evaluating medical practitioner for the medical procedure performed by the medical practitioner.

[0159] FIG. 14 is an example segment selection interface 1400 for a medical practitioner to select a segment of data describing performance of a medical procedure for evaluation by an evaluating medical practitioner. In some embodiments, the segment selection interface 1400 is presented after the collaborative medical platform receives a selection of an evaluating medical practitioner. However, in other embodiments, the segment selection interface 1400 is displayed after the evaluation interface 1100 and prior to the framework interface 1200 or at a different time relative to selection of a framework and selection of an evaluating medical practitioner. In the example of FIG. 14, the segment selection interface displays video data 1405 of the medical procedure. In some embodiments, the segment selection interface 1400 displays telemetry data captured during performance of the medical procedure or displays a combination of video data 1405 of the medical procedure and telemetry data captured during performance of the medical procedure. In various embodiments, the segment selection interface 1400 includes a media player that plays the video data 1405 of the medical procedure to the medical practitioner. The media player includes controls for changing a playback speed of the video data 1405 and for navigating through the video data 1405 to simplify navigation through the video data 1405 by the medical practitioner.

[0160] Additionally, the segment selection interface 1400 includes a starting time 1410 and an ending time 1415 for a segment. In some embodiments, the medical practitioner manually enters the starting time 1410 in a corresponding interface element of the segment selection interface 1400 and manually enters the ending time 1415 in a corresponding interface element of the segment selection interface 1400 to specify a time range of data describing performance of the medical procedure (e.g., the video data 1405, telemetry data, a combination of video data and telemetry data) including a segment. Alternatively or additionally, the medical practitioner performs a specific interaction with the video data 1405, and the time when the medical practitioner performed the specific interaction comprises the starting time 1410 of the segment. Similarly, the medical practitioner performs an additional specific interaction with the video data at a later time, and later time comprises the ending time 1415 of the segment. The segment selection interface 1400 displays the starting time 1410 and the ending time 1415 of the segment

to allow the medical practitioner to review or to modify the time interval comprising the segment.

[0161] In various embodiments, the collaborative medical platform 140 determines the ending time 1415 of the segment based on the starting time 1410 in various embodiments. For example, a segment has a specific duration, so the collaborative medical platform 140 increments the starting time 1410 by a specific time interval to determine the ending time 1415. In some embodiments, the specific time interval is used for each segment. Alternatively, different specific time intervals may be selected for different segments, and the medical practitioner selects a specific time interval from a set presented by the segment selection interface 1400 for the segment. Maintaining a set of specific time intervals allows the medical practitioner to vary a duration of different segments.

[0162] In some embodiments, such as the example shown in FIG. 14, the segment selection interface 1400 includes a video data timeline 1420, which may indicate specific times within the video data 1405. For example, the video data timeline 1420 includes an indication corresponding to each 15-minute interval in the video data 1405. In response to the medical practitioner selecting a portion of the video data timeline 1420, the collaborative medical platform 140 updates the portion of the video data 1405 presented by the segment selection interface 1400 to start at a time corresponding to the selected portion of the video data timeline 1420. The video data timeline 1420 displays a segment identifier 1425 visually indicating the starting time 1410 and the ending time 1415 of the selected segment relative to the overall length of time of the video data 1405, allowing the medical practitioner to easily identify a location of the selected segment within the video data 1405.

[0163] The segment specified by the starting time 1410 and the ending time 1415 includes video data occurring between the starting time 1410 and the ending time 1415. Further, in various embodiments, the segment includes telemetry data captured during performance of the medial procedure between the starting time 1410 and the ending time 1415 along with the video data 1405 captured between the starting time 1410 and the ending time 1415. The collaborative medical platform 140 may perform one or more preprocessing steps to synchronize video data 1405 and telemetry data captured between the starting time 1410 and the ending time 1410. In some embodiments, the segment selection interface 1400 includes an interface element allowing the medical practitioner to select whether the segment includes video data and telemetry data, video data only, or telemetry data only.

[0164] FIG. 15 is an example evaluation result interface 1500 presenting evaluation results for a medical practitioner performing a medical procedure. The evaluation result interface 1500

includes a medical practitioner identifier 1505 of the medical practitioner who requested evaluation. For example, the medical practitioner identifier 1505 is a name of the medical practitioner, an image of the medical practitioner, a username of the medical practitioner, or any other information uniquely identifying the medical practitioner. In various embodiments, such as the example shown in FIG. 15, the evaluation result interface 1500 also presents medical practitioner information 1510 about the medical practitioner requesting evaluation. In some embodiments, the medical practitioner information 1510 is presented in response to an interaction with the medical practitioner identifier 1505. Example medical practitioner information 1510 includes: a role of the medical practitioner in the medical procedure, a number of years of experience of the medical practitioner, a number of medical procedures performed by the medical practitioner, a number of medical procedures having a common type as the medical procedure selected for evaluation performed by the medical practitioner, one or more prior evaluation results for the medical practitioner, or other information about the medical practitioner.

[0165] The evaluation result interface 1500 also presents an evaluating medical practitioner identifier 1515 for the evaluating medical practitioner. For example, the evaluating medical practitioner identifier 1515 is a name of the evaluating medical practitioner, an image of the evaluating medical practitioner, or other information uniquely identifying the evaluating medical practitioner. Additionally, the evaluation result interface 1500 identifies a type 1520 of the medical procedure selected for evaluation. Performing one or more interactions with the type 1520 of the medical procedure selected for evaluation causes presentation of procedure details 1525 in various embodiments. The procedure details 1525 include contextual information about the medical procedure selected for evaluation. Example procedure details 1525 include: a gender of the patient on which the medical procedure was performed, an age of the patient on which the medical procedure was performed, one or more physical characteristics of the patient on which the medical procedure was performed, one or more other medical practitioners associated with the medical procedure, or other information about the medical procedure.

[0166] To present evaluation results to the medical practitioner, the evaluation result interface 1500 includes a framework identifier 1530 identifying the framework selected by the medical practitioner for evaluation. The evaluation result interface 1500 also identifies one or more categories in the framework along with a corresponding evaluation value for each category. In the example of FIG. 15, the evaluation result interface 1500 displays information identifying a category 1535 (e.g., a name of the category 1535) and displays an evaluation value 1540 for the category 1535 proximate to the information identifying the category 1535. Combinations of categories of the framework and corresponding evaluation values comprise the evaluation results

for the medical practitioner for the medical procedure. In some embodiments, the evaluation results also include an evaluation summary 1545 comprising text data describing reasoning or rationale for one or more of the evaluation values 1540 or other information from the evaluating medical practitioner.

[0167] The evaluation result interface 1500 also displays video data 1550 of the medical procedure selected for evaluation. In various embodiments, the evaluation result interface 1500 includes a media player having one or more controls allowing the medical practitioner to view or to navigate through the video data 1550 of the medical procedure. As further described above in conjunction with FIG. 2, the evaluating medical practitioner may provide one or more comments when evaluating the medical procedure. A comment may be associated with a specific time in the video data 1550 (or in telemetry data captured during the medical procedure). The evaluation interface 1500 displays a comment 1555, which comprises text data in various embodiments, and displays a specific time 1560 associated with the comment 1555 proximate to the comment 1555. In various embodiments, the specific time 1560 identifies a starting time of a portion of data describing performance of the medical procedure (e.g., the video data 1550) corresponding to the comment 1555. The medical practitioner may select the specific time 1560 associated with a comment 1550 via the evaluation result interface 1500 (or select the comment 1550 via the evaluation result interface 1500) to initiate presentation of the video data 1550 starting at the specific time 1560 by the evaluation result interface 1500, simplifying review of specific portions of the video data 1550 (or other data describing performance of the medical procedure) corresponding to individual comments. In some embodiments, the evaluation result interface 1500 presents telemetry data, or other data describing performance of the medical procedure, in conjunction with the video data 1550 (or in place of the video data 1550).

[0168] FIG. 16 is an example embodiment of a process for a medical practitioner obtaining evaluation of performance of a medical procedure by an evaluating medical practitioner via a collaborative medical platform 140. The collaborative medical platform 140 receives 1602 a request for evaluation of performance during a medical procedure from a medical practitioner and receives 1604 a selection of the medical procedure for evaluation from the medical practitioner. For example, the collaborative medical platform 140 identifies medical procedures associated with the medical practitioner in response to receiving 1602 the request and receives 1604 a selection of an identified medical procedure from the medical practitioner. As another example, the request for evaluation of performance during the medical procedure includes an identifier of the medical procedure to be evaluated.

[0169] Additionally, the collaborative medical platform 140 receives 1606 a selection of a framework for evaluating the selected medical procedure from the medical practitioner. Each

framework includes one or more categories corresponding to different skills or techniques applicable to performing a medical procedure. A framework also includes guidelines or standards for performing different types of actions or techniques or includes criteria for evaluating one or more actions or techniques. In various embodiments, the medical practitioner selects a framework from a set of frameworks identified by the collaborative medical platform 140.

[0170] The collaborative medical platform 140 receives 1608 a selection of a segment of data describing performance of the selected medical procedure from the medical practitioner. Data describing performance of the selected medical procedure includes video data, telemetry data, or a combination thereof captured during performance of the selected medical procedure. In various embodiments, the collaborative medical platform 140 retrieves stored data describing performance of the selected medical procedure and the medical practitioner selects 1608 a starting time and an ending time of the stored data describing performance of the selected medical procedure to identify the segment. The segment includes a portion of the data describing performance of the selected medical procedure between the starting time and the ending time. The medical practitioner specifies a starting time and the collaborative medical platform 140 increments the starting time by a specific time interval to determine the ending time of the segment in some embodiments. The specific time interval may be predefined by the collaborative medical platform 140 or may be specified by the medical practitioner in various embodiments. The medical practitioner may select 1608 multiple segments of the data describing performance of the medical procedure and select 1606 multiple frameworks, allowing use of different frameworks to evaluate different segments.

[0171] Based on the selected medical procedure, selected framework, selected evaluating medical practitioner, and selected segment of data describing performance of the selected medical procedure, the collaborative medical platform 1612 generates an evaluation message and transmits the evaluation message to the evaluating medical practitioner. In response to receiving the evaluation message, the evaluating medical practitioner reviews the selected segment of the data describing performance of the selected medical procedure in view of the selected framework and generates evaluation results that comprise evaluation values for each category in the selected framework. As further described above in conjunction with FIG. 2, the evaluation results may also include comments associated with specific times within the selected segment of data describing performance of the medical procedure. The collaborative medical platform 140 presents 1614 the evaluation results to the medical practitioner through an evaluation result interface, further described above in conjunction with FIG. 15, or other communication channel. In some embodiments, the collaborative medical platform 140 selects one or more educational

content items for the medical practitioner based on the evaluation results, as further described above in conjunction with FIG. 2. For example, the collaborative medical platform 140 selects an educational content item associated with a type of the selected medical practitioner and having a baseline criterion specifying a value of a category of the selected framework that is greater than an evaluation value for the category of the selected framework by at least a threshold amount.

[0172] In alternative embodiments, the collaborative medical platform 140 applies one or more trained evaluation models to the selected segment of the data describing performance of the selected medical procedure and to the selected framework. As further described above in conjunction with FIG. 2, an evaluation model generates a predicted evaluation value for a category of the selected framework based on the selected segment of the data describing performance of the selected medical procedure. The predicted evaluation values may be presented in conjunction with their corresponding categories in some embodiments. Further, the collaborative medical platform may select one or more educational content items for the medical practitioner based on one or more of the predicted evaluation values in various embodiments. Hence, in some embodiments, the collaborative medical platform 140 automatically generates the evaluation results using one or more trained models rather than receiving the evaluation results from the selected medical practitioner.

[0173] The described embodiments incorporate multiple technical improvements that improve the functioning of computer systems, machine learning techniques, data management systems (particularly as related to healthcare data management), computer-based user interfaces, robotic and/or other medical instrumentation systems, and other technologies and technical fields. For example, the described embodiments provide technical improvements in data availability and data privacy by enabling automated processing of sensitive and/or restricted data such as operating room video, patient health records, or other sensitive health data.

[0174] The described embodiments furthermore include improvements in machine learning methods in that they combine information from disparate data sources including medical equipment telemetry data, video data, and mobile device data to improve predictive power relative to traditional machine learning techniques. Further still, the described embodiments provide technical improvements in treatment of medical conditions by enabling generation of various notifications, recommendations, or other content tailored to specific medical practitioners that enable them to improve their practice and accordingly results in better patient outcomes.

[0175] Furthermore, the described embodiments include technical improvements in the field of robotic-assisted surgery by enabling automated configuration of surgical robots based on the

accumulated and aggregated healthcare data associated with patients, facilities, and practitioners. This results in improved performance of the robot, improved human-robot interactions, and improved patient outcomes.

[0176] The foregoing description of the embodiments has been presented for the purpose of illustration; it is not intended to be exhaustive or to limit the embodiments to the precise forms disclosed. Persons skilled in the relevant art can appreciate that many modifications and variations are possible in light of the above disclosure.

[0177] Some portions of this description describe the embodiments in terms of algorithms and symbolic representations of operations on information. These operations, while described functionally, computationally, or logically, are understood to be implemented by computer programs or equivalent electrical circuits, microcode, or the like. Furthermore, it has also proven convenient at times, to refer to these arrangements of operations as modules, without loss of generality. The described operations and their associated modules may be embodied in software, firmware, hardware, or any combinations thereof.

[0178] Any of the steps, operations, or processes described herein may be performed or implemented with one or more hardware or software modules, alone or in combination with other devices. Embodiments may also relate to an apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, and/or it may include a general-purpose computing device selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a tangible non-transitory computer readable storage medium or any type of media suitable for storing electronic instructions and coupled to a computer system bus. Furthermore, any computing systems referred to in the specification may include a single processor or may include architectures employing multiple processor designs for increased computing capability.

[0179] As used herein, unless expressly stated to the contrary, "or" refers to an inclusive "or" and not to an exclusive "or." For example, a condition "A or B" is satisfied by any one of the following: A is true (or present) and B is false (or not present); A is false (or not present) and B is true (or present); and both A and B are true (or present). Similarly, a condition "A, B, or C" is satisfied by any combination of A, B, and C being true (or present). As a non-limiting example, the condition "A, B, or C" is satisfied when A and B are true (or present) and C is false (or not present). Similarly, as another non-limiting example, the condition "A, B, or C" is satisfied when A is true (or present) and B and C are false (or not present).

[0180] Finally, the language used in the specification has been principally selected for readability and instructional purposes, and it may not have been selected to delineate or

circumscribe the inventive subject matter. It is therefore intended that the scope is not limited by this detailed description, but rather by any claims that issue on an application based hereon. Accordingly, the disclosure of the embodiments is intended to be illustrative, but not limiting, of the scope of the invention, which is set forth in the following claims.

WHAT IS CLAIMED IS:

1. A method for evaluating a medical practitioner performing a medical procedure through an online collaborative medical platform, the method comprising:

receiving, at the collaborative medical platform, a request from the medical practitioner for evaluation;

receiving, at the collaborative medical platform, a selection of the medical procedure for evaluation from the medical practitioner;

receiving a selection of a framework for evaluating the medical practitioner based on the medical procedure at the collaborative medical platform, the framework including categories corresponding to different skills or techniques applicable to performing the medical procedure;

receiving a selection of an evaluating medical practitioner at the collaborative medical platform from the medical practitioner;

receiving a selection of a segment of data describing performance of the medical procedure by the medical practitioner, the section including a portion of the data describing performance of the medical procedure between a starting time and an ending time;

obtaining evaluation results from the evaluating medical practitioner, the evaluation results including an evaluation value for each category of the framework from the evaluating medical practitioner; and

presenting the evaluation results to the medical practitioner.

2. The method of claim 1, further comprising:

selecting an educational content item associated with at least one baseline criterion that is not satisfied by an evaluation value for a category of the framework, the educational content item associated with a type of the medical procedure; and

presenting the selected educational content item to the medical practitioner.

3. The method of claim 2, wherein selecting the educational content item associated with at least one baseline criterion that is not satisfied by the evaluation value for the category of the framework, the educational content item associated with a type of the medical procedure comprises:

selecting an educational content item having a baseline criterion specifying a value for the category of the framework that is at least a threshold amount greater than the evaluation value for the category of the framework.

4. The method of claim 2, wherein selecting the educational content item associated with at least one baseline criterion that is not satisfied by the evaluation value for the category of the framework, the educational content item associated with a type of the medical procedure comprises:

determining an aggregated value for a category of the framework based on the evaluation result for the category of the framework and one or more previously determined evaluation results for the category of the framework for the medical practitioner; and

selecting an educational content item associated with at least one baseline criterion that is not satisfied by the aggregated value for a category of the framework, the educational content item associated with a type of the medical procedure.

5. The method of claim 1, further comprising:

applying an evaluation model to the segment of the data describing performance of the medical procedure and to the framework, the evaluation model generating a predicted evaluation value for a category of the framework based on the segment of the data describing performance of the medical procedure;

scoring the evaluation model using a loss function based on a difference between the predicted evaluation value for the category of the framework and an evaluation value for the category of the framework; and

updating one or more parameters of the evaluation model by backpropagation based on the scoring.

6. The method of claim 1, wherein the data describing performance of the medical procedure includes video data captured during performance of the medical procedure and telemetry data captured by one or more sensors during performance of the medical procedure.

7. The method of claim 1, wherein the evaluation results further include one or more comments from the evaluating medical practitioner, a comment associated with a specific time in the segment of the data describing performance of the medical procedure.

8. The method of claim 1, wherein receiving the selection of the segment of data describing performance of the medical procedure by the medical practitioner comprises:

receiving a selection of the starting time within the segment of the data describing the performance of the medical procedure by the medical practitioner from the medical practitioner; and

determining, by the collaborative medical platform, the ending time by the collaborative medical platform incrementing the starting time by a specific time interval.

9. A non-transitory computer-readable storage medium storing instructions for evaluating a medical practitioner performing a medical procedure through an online collaborative medical platform, the instructions when executed by one or more processors causing the one or more processors to perform steps comprising:

receiving, at the collaborative medical platform, a request from the medical practitioner for evaluation;

receiving, at the collaborative medical platform, a selection of the medical procedure for evaluation from the medical practitioner;

receiving a selection of a framework for evaluating the medical practitioner based on the medical procedure at the collaborative medical platform, the framework including categories corresponding to different skills or techniques applicable to performing the medical procedure;

receiving a selection of an evaluating medical practitioner at the collaborative medical platform from the medical practitioner;

receiving a selection of a segment of data describing performance of the medical procedure by the medical practitioner, the section including a portion of the data describing performance of the medical procedure between a starting time and an ending time;

obtaining evaluation results from the evaluating medical practitioner, the evaluation results including an evaluation value for each category of the framework from the evaluating medical practitioner; and

presenting the evaluation results to the medical practitioner.

10. The non-transitory computer-readable storage medium of claim 9, further storing instructions that, when executed by one or more processors, cause the one or more processors to perform steps comprising:

selecting an educational content item associated with at least one baseline criterion that is not satisfied by an evaluation value for a category of the framework, the educational content item associated with a type of the medical procedure; and

presenting the selected educational content item to the medical practitioner.

11. The non-transitory computer-readable storage medium of claim 10, wherein selecting the educational content item associated with at least one baseline criterion that is not satisfied by the evaluation value for the category of the framework, the educational content item associated with a type of the medical procedure comprises:

selecting an educational content item having a baseline criterion specifying a value for the category of the framework that is at least a threshold amount greater than the evaluation value for the category of the framework.

12. The non-transitory computer-readable storage medium of claim 10, wherein selecting the educational content item associated with at least one baseline criterion that is not satisfied by the evaluation value for the category of the framework, the educational content item associated with a type of the medical procedure comprises:

determining an aggregated value for a category of the framework based on the evaluation result for the category of the framework and one or more previously determined evaluation results for the category of the framework for the medical practitioner; and

selecting an educational content item associated with at least one baseline criterion that is not satisfied by the aggregated value for a category of the framework, the educational content item associated with a type of the medical procedure.

13. The non-transitory computer-readable storage medium of claim 9, further storing instructions that, when executed by one or more processors, cause the one or more processors to perform steps comprising:

applying an evaluation model to the segment of the data describing performance of the medical procedure and to the framework, the evaluation model generating a predicted evaluation value for a category of the framework based on the segment of the data describing performance of the medical procedure;

scoring the evaluation model using a loss function based on a difference between the predicted evaluation value for the category of the framework and an evaluation value for the category of the framework; and

updating one or more parameters of the evaluation model by backpropagation based on the scoring.

14. The non-transitory computer-readable storage medium of claim 9, wherein the data describing performance of the medical procedure includes video data captured during performance of the medical procedure and telemetry data captured by one or more sensors during performance of the medical procedure.

15. The non-transitory computer-readable storage medium of claim 9, wherein the evaluation results further include one or more comments from the evaluating medical practitioner, a comment associated with a specific time in the segment of the data describing performance of the medical procedure.

16. The non-transitory computer-readable storage medium of claim 9, wherein receiving the selection of the segment of data describing performance of the medical procedure by the medical practitioner comprises:

receiving a selection of the starting time within the segment of the data describing the performance of the medical procedure by the medical practitioner from the medical practitioner; and

determining, by the collaborative medical platform, the ending time by the collaborative medical platform incrementing the starting time by a specific time interval.

17. A method for evaluating a medical practitioner performing a medical procedure through an online collaborative medical platform, the method comprising:

receiving, at the collaborative medical platform, a request from the medical practitioner for evaluation;

receiving, at the collaborative medical platform, a selection of the medical procedure for evaluation from the medical practitioner;

receiving a selection of a framework for evaluating the medical practitioner based on the medical procedure at the collaborative medical platform, the framework including categories corresponding to different skills or techniques applicable to performing the medical procedure;

receiving a selection of a segment of data describing performance of the medical procedure by the medical practitioner, the section including a portion of the data describing performance of the medical procedure between a starting time and an ending time;

generating, by the collaborative medical platform, evaluation results including a predicted evaluation value for a category of the framework by applying an evaluation model to a combination of the framework and the segment of data describing performance of the medical procedure, the evaluation model trained by:

obtaining plurality of training examples, each training example including a training segment of data describing performance of a training medical procedure and a training framework, each training example having a label indicating an evaluation value for the

category based on the training framework and the training segment;

applying the evaluation model to each training example to generate a predicted evaluation value for the category based on the training segment and the training framework;

scoring the evaluation model using a loss function and the label of the training example; and

updating one or more parameters of the evaluation model by backpropagation based on the scoring until one or more criteria are satisfied; and

presenting the evaluation results to the medical practitioner.

18. The method of claim 17, further comprising:

selecting an educational content item associated with at least one baseline criterion that is not satisfied by an evaluation value for a category of the framework, the educational content item associated with a type of the medical procedure; and

presenting the selected educational content item to the medical practitioner.

19. The method of claim 17, wherein the data describing performance of the medical procedure includes video data captured during performance of the medical procedure and telemetry data captured by one or more sensors during performance of the medical procedure.

20. The method of claim 17, wherein the evaluation results further include one or more comments from the evaluating medical practitioner, a comment associated with a specific time in the segment of the data describing performance of the medical procedure.

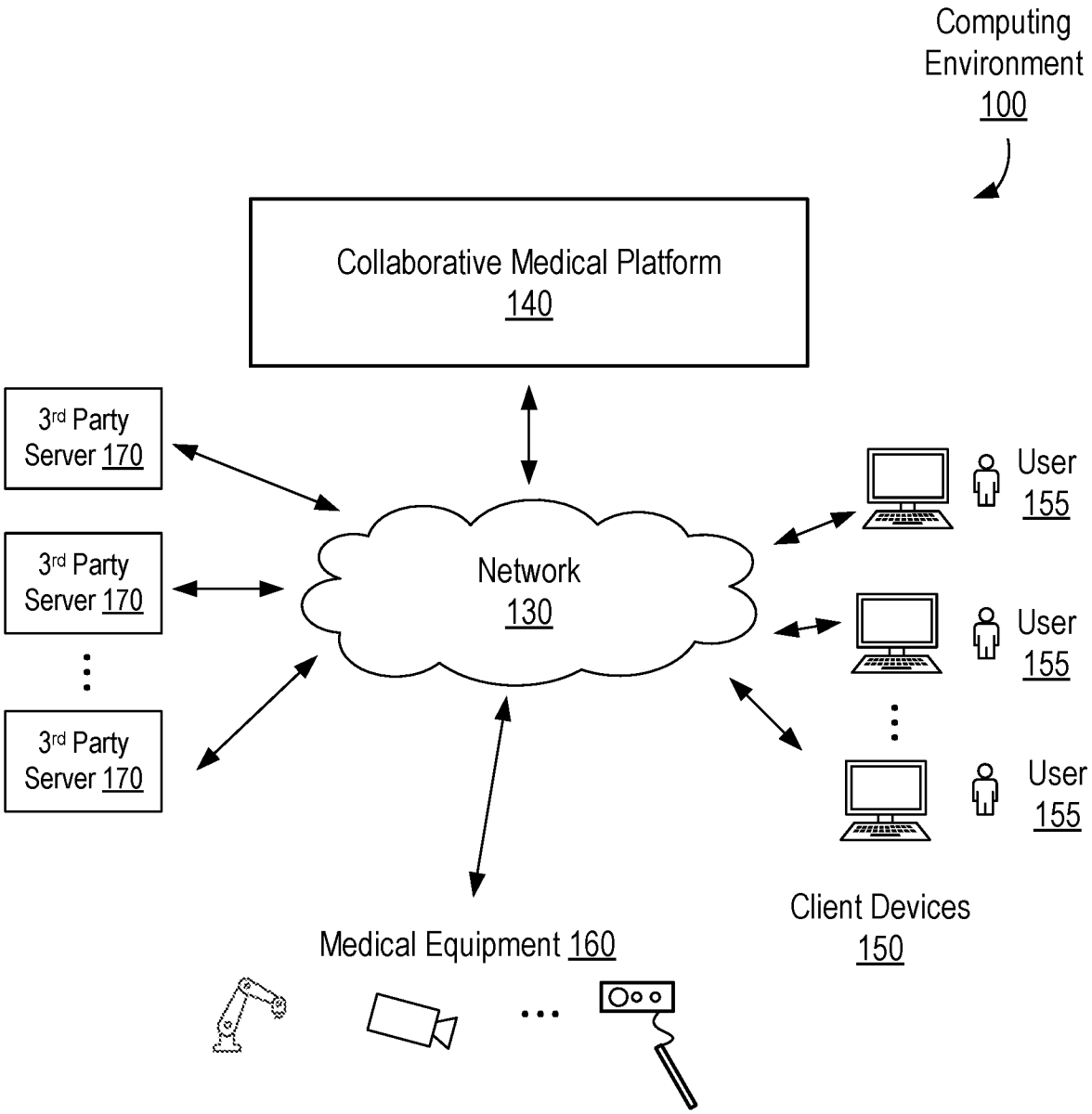
Computing Environment 100
Collaborative Medical Platform 140
3rd Party Server 170
3rd Party Server 170
3rd Party Server 170
Network 130
User 155
User 155
User 155
Client Devices 150
Medical Equipment 160

FIG. 1

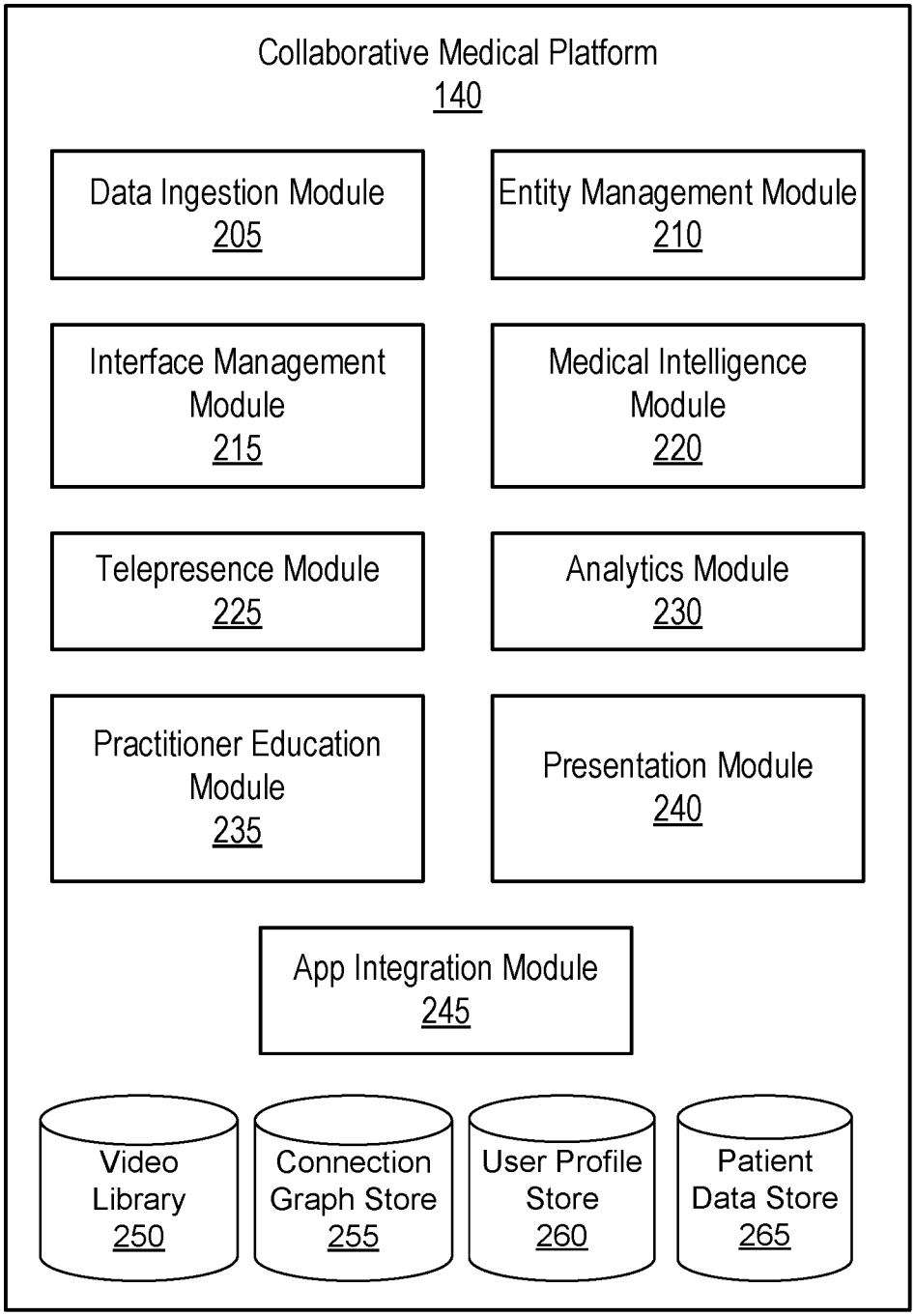
Collaborative Medical Platform
140
Data Ingestion Module
205
Entity Management Module
210
Interface Management Module
215
Medical Intelligence Module
220
Telepresence Module
225
Analytics Module
230
Practitioner Education Module
235
Presentation Module
240
App Integration Module
245
Video Library
250
Connection Graph Store
255
User Profile Store
260
Patient Data Store
265

FIG. 2

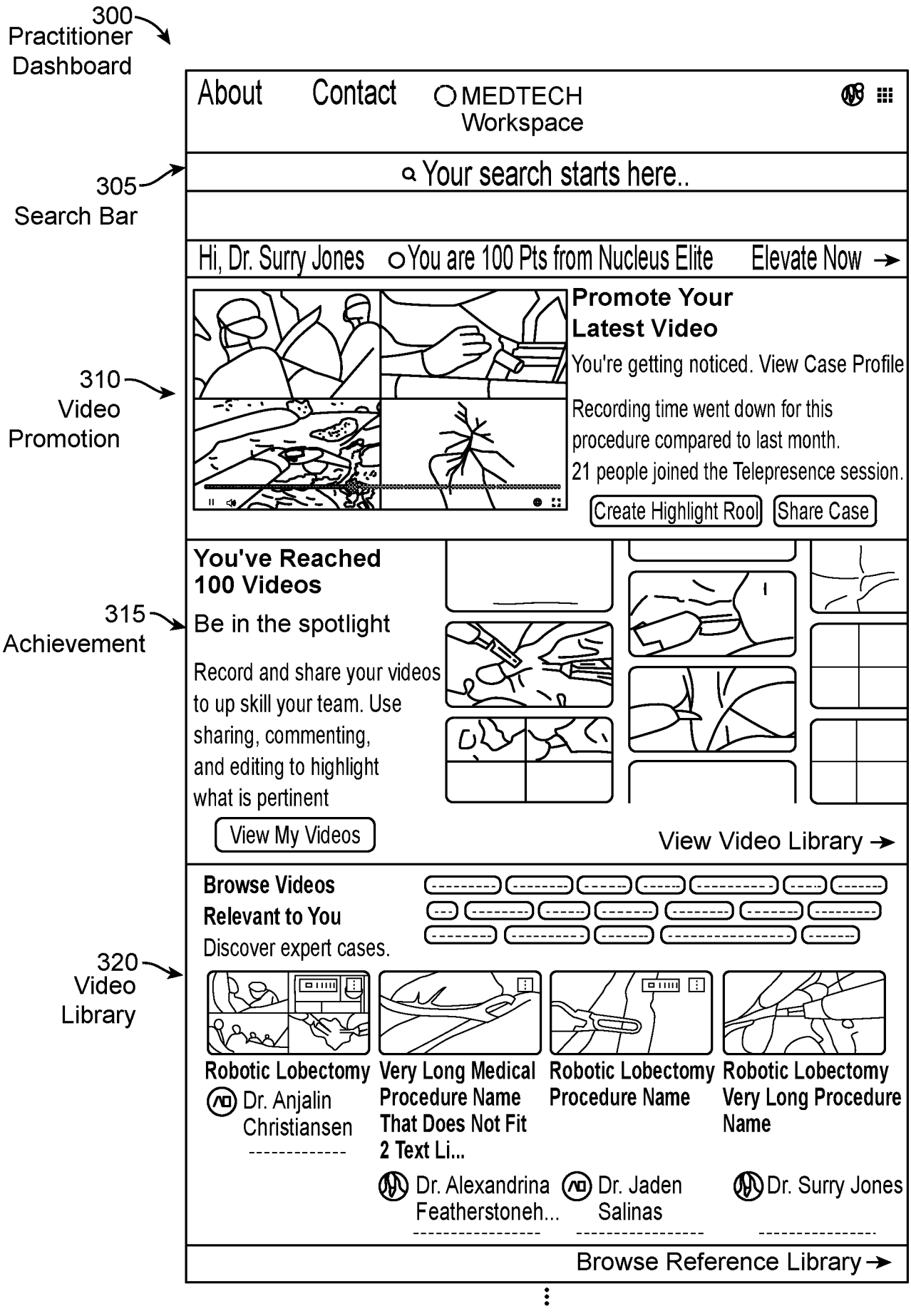
300
Practitioner Dashboard
About
Contact
MEDTECH Workspace
305
Search Bar
Your search starts here..
Hi, Dr. Surry Jones
You are 100 Pts from Nucleus Elite
Elevate Now
310
Video Promotion
Promote Your Latest Video
You're getting noticed. View Case Profile
Recording time went down for this procedure compared to last month.
21 people joined the Telepresence session.
Create Highlight Rool
Share Case
315
Achievement
You've Reached 100 Videos
Be in the spotlight
Record and share your videos to up skill your team. Use sharing, commenting, and editing to highlight what is pertinent
View My Videos
View Video Library
320
Video Library
Browse Videos Relevant to You
Discover expert cases.
Robotic Lobectomy
Dr. Anjalin Christiansen
Very Long Medical Procedure Name That Does Not Fit 2 Text Li...
Dr. Alexandrina Featherstoneh...
Robotic Lobectomy Procedure Name
Dr. Jaden Salinas
Robotic Lobectomy Very Long Procedure Name
Dr. Surry Jones
Browse Reference Library

FIG. 3A

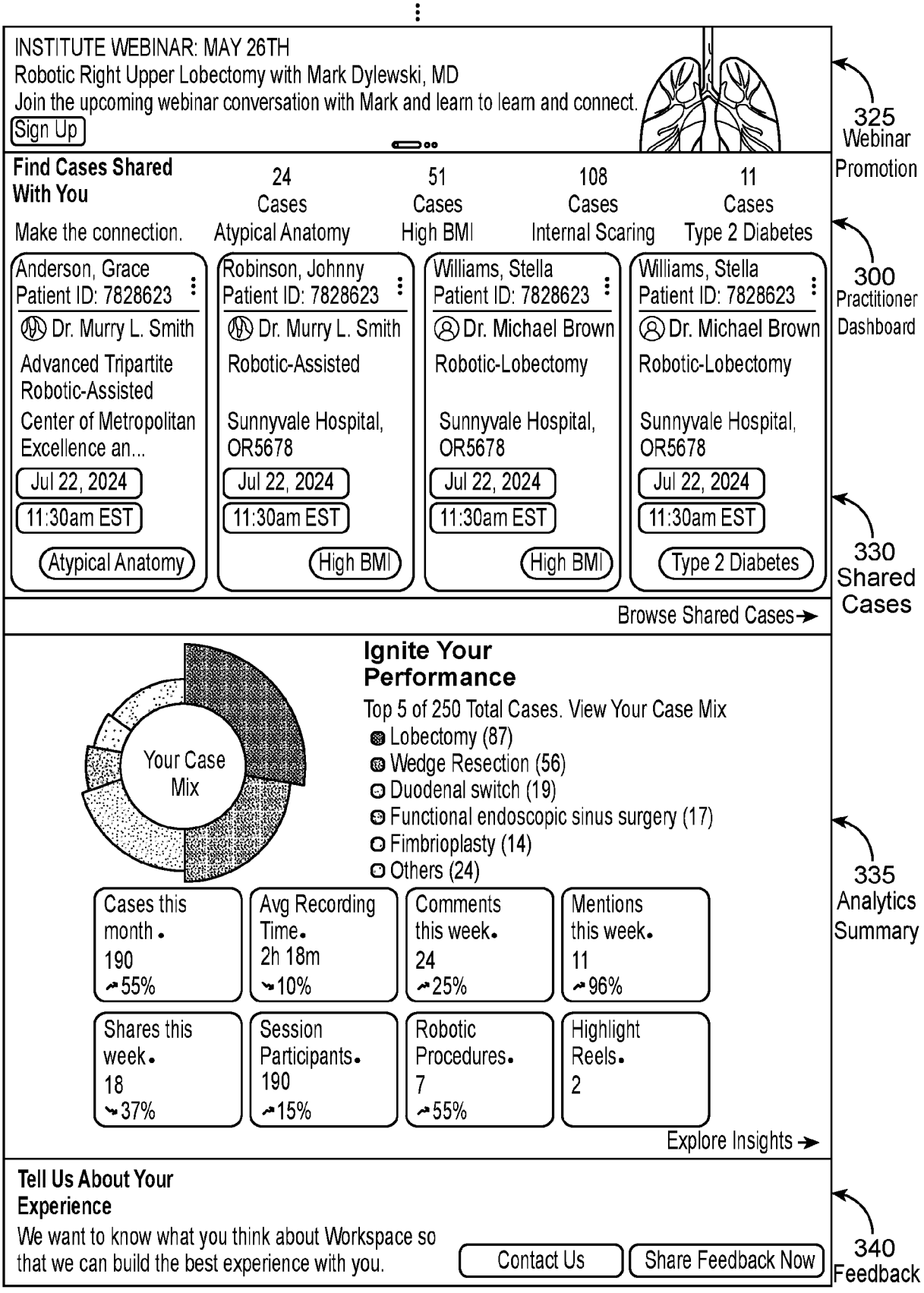
INSTITUTE WEBINAR: MAY 26TH
Robotic Right Upper Lobectomy with Mark Dylewski, MD
Join the upcoming webinar conversation with Mark and learn to learn and connect.
Sign Up
325 Webinar Promotion
Find Cases Shared With You
Make the connection.
24 Cases Atypical Anatomy
51 Cases High BMI
108 Cases Internal Scaring
11 Cases Type 2 Diabetes
300 Practitioner Dashboard
Anderson, Grace
Patient ID: 7828623
Dr. Murry L. Smith
Advanced Tripartite Robotic-Assisted Center of Metropolitan Excellence an...
Jul 22, 2024
11:30am EST
Atypical Anatomy
Robinson, Johnny
Patient ID: 7828623
Dr. Murry L. Smith
Robotic-Assisted
Sunnyvale Hospital, OR5678
Jul 22, 2024
11:30am EST
High BMI
Williams, Stella
Patient ID: 7828623
Dr. Michael Brown
Robotic-Lobectomy
Sunnyvale Hospital, OR5678
Jul 22, 2024
11:30am EST
High BMI
Williams, Stella
Patient ID: 7828623
Dr. Michael Brown
Robotic-Lobectomy
Sunnyvale Hospital, OR5678
Jul 22, 2024
11:30am EST
Type 2 Diabetes
330 Shared Cases
Browse Shared Cases
Your Case Mix
Ignite Your Performance
Top 5 of 250 Total Cases. View Your Case Mix
Lobectomy (87)
Wedge Resection (56)
Duodenal switch (19)
Functional endoscopic sinus surgery (17)
Fimbrioplasty (14)
Others (24)
Cases this month. 190 55%
Avg Recording Time. 2h 18m 10%
Comments this week. 24 25%
Mentions this week. 11 96%
Shares this week. 18 37%
Session Participants. 190 15%
Robotic Procedures. 7 55%
Highlight Reels. 2
335 Analytics Summary
Explore Insights
Tell Us About Your Experience
We want to know what you think about Workspace so that we can build the best experience with you.
Contact Us
Share Feedback Now
340 Feedback

FIG. 3B

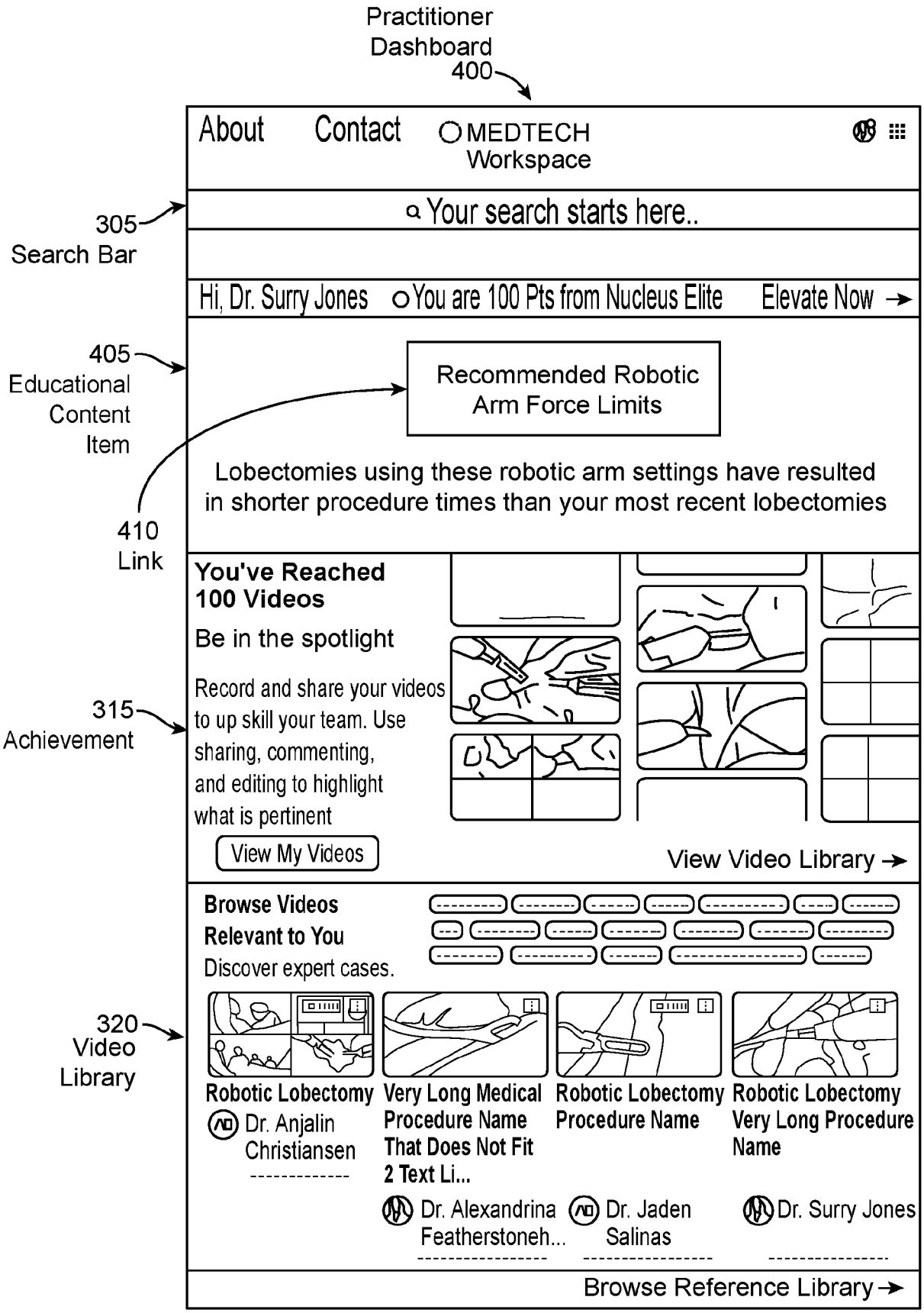
Practitioner Dashboard
400
About
Contact
MEDTECH Workspace
305
Search Bar
Your search starts here..
Hi, Dr. Surry Jones
You are 100 Pts from Nucleus Elite
Elevate Now
405
Educational Content Item
Recommended Robotic Arm Force Limits
410
Link
Lobectomies using these robotic arm settings have resulted in shorter procedure times than your most recent lobectomies
You've Reached 100 Videos
Be in the spotlight
315
Achievement
Record and share your videos to up skill your team. Use sharing, commenting, and editing to highlight what is pertinent
View My Videos
View Video Library
Browse Videos Relevant to You
Discover expert cases.
320
Video Library
Robotic Lobectomy
Dr. Anjalin Christiansen
Very Long Medical Procedure Name That Does Not Fit 2 Text Li...
Dr. Alexandrina Featherstoneh...
Robotic Lobectomy Procedure Name
Dr. Jaden Salinas
Robotic Lobectomy Very Long Procedure Name
Dr. Surry Jones
Browse Reference Library

FIG. 4

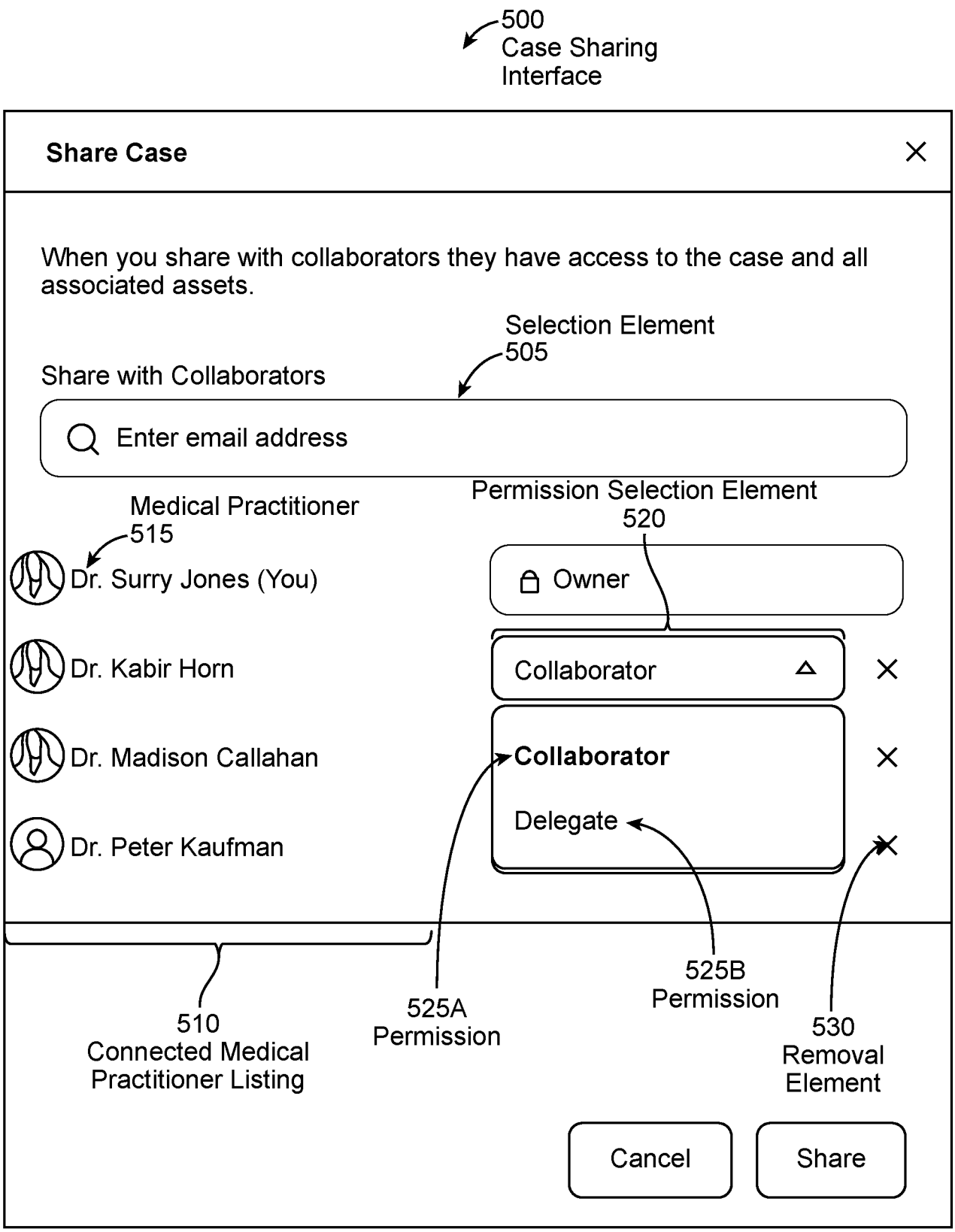
500
Case Sharing
Interface
Share Case
When you share with collaborators they have access to the case and all associated assets.
Selection Element
505
Share with Collaborators
Enter email address
Medical Practitioner
515
Permission Selection Element
520
Dr. Surry Jones (You)
Owner
Dr. Kabir Horn
Collaborator
Dr. Madison Callahan
Collaborator
Delegate
Dr. Peter Kaufman
510
Connected Medical Practitioner Listing
525A
Permission
525B
Permission
530
Removal
Element
Cancel
Share

FIG. 5

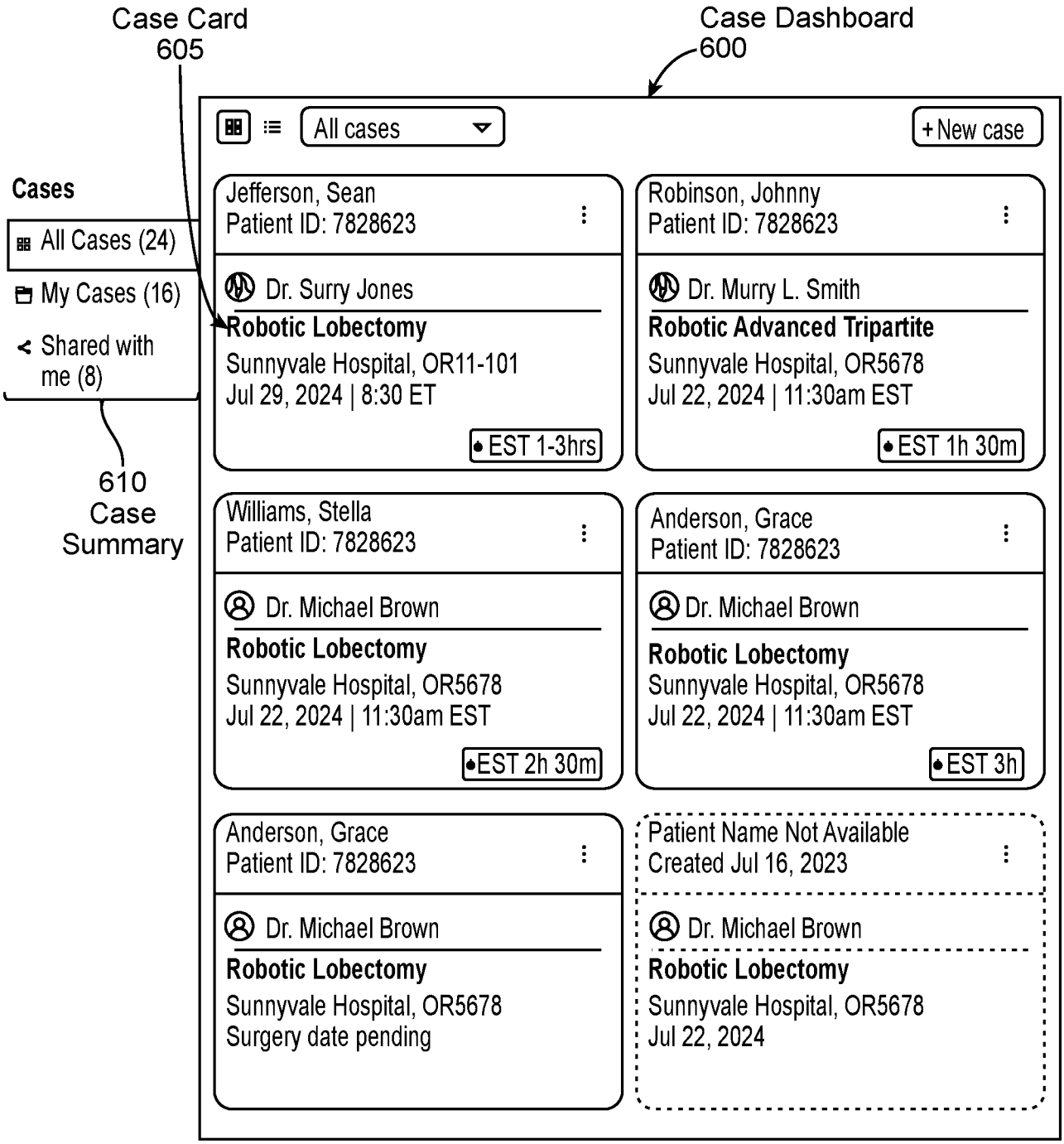
Case Card
605
Case Dashboard
600
All cases
+New case
Cases
All Cases (24)
My Cases (16)
Shared with me (8)
610
Case Summary
Jefferson, Sean
Patient ID: 7828623
Dr. Surry Jones
Robotic Lobectomy
Sunnyvale Hospital, OR11-101
Jul 29, 2024 | 8:30 ET
EST 1-3hrs
Robinson, Johnny
Patient ID: 7828623
Dr. Murry L. Smith
Robotic Advanced Tripartite
Sunnyvale Hospital, OR5678
Jul 22, 2024 | 11:30am EST
EST 1h 30m
Williams, Stella
Patient ID: 7828623
Dr. Michael Brown
Robotic Lobectomy
Sunnyvale Hospital, OR5678
Jul 22, 2024 | 11:30am EST
EST 2h 30m
Anderson, Grace
Patient ID: 7828623
Dr. Michael Brown
Robotic Lobectomy
Sunnyvale Hospital, OR5678
Jul 22, 2024 | 11:30am EST
EST 3h
Anderson, Grace
Patient ID: 7828623
Dr. Michael Brown
Robotic Lobectomy
Sunnyvale Hospital, OR5678
Surgery date pending
Patient Name Not Available
Created Jul 16, 2023
Dr. Michael Brown
Robotic Lobectomy
Sunnyvale Hospital, OR5678
Jul 22, 2024

FIG. 6

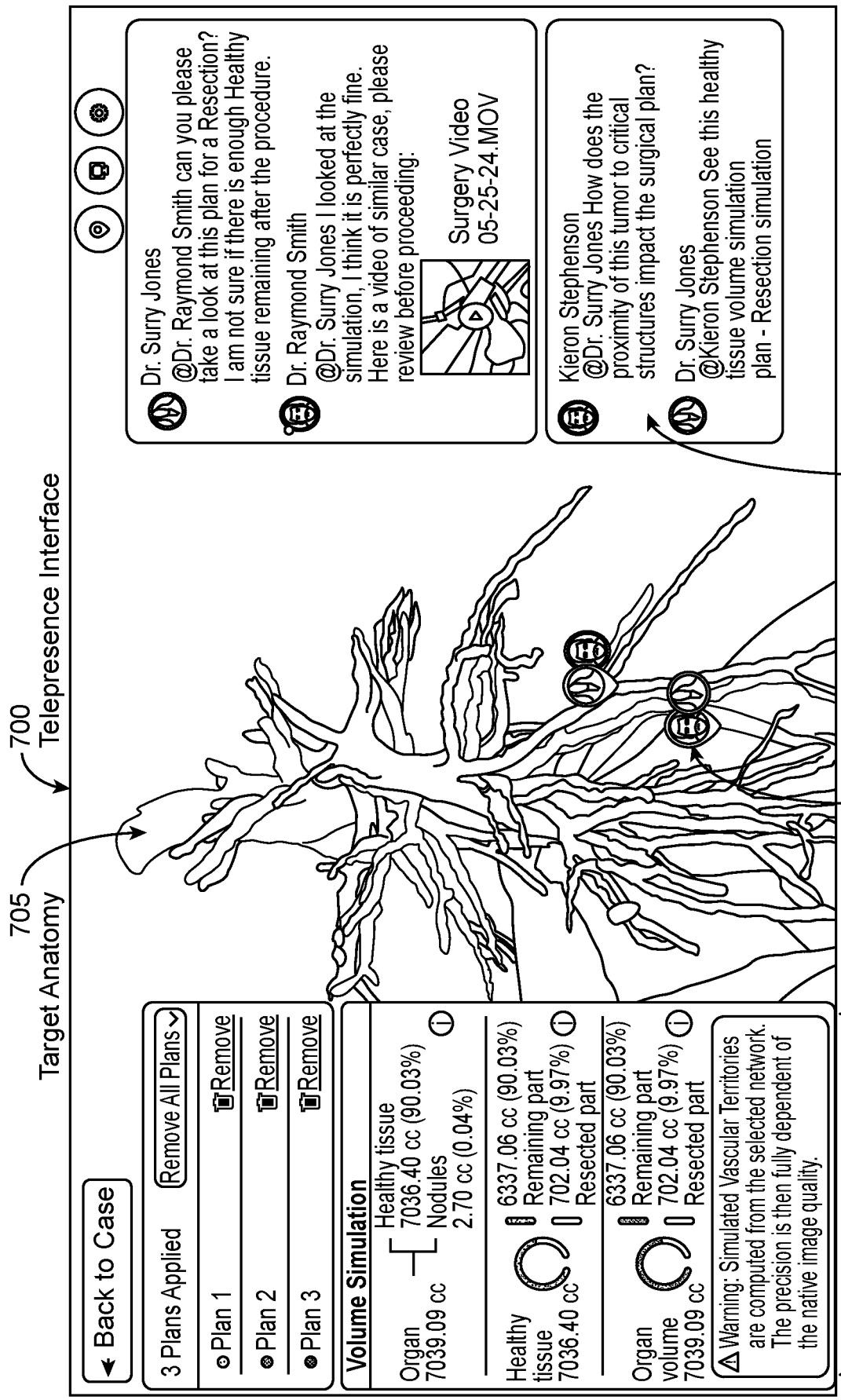
700
Telepresence Interface
705
Target Anatomy
Back to Case
3 Plans Applied
Remove All Plans
Plan 1
Remove
Plan 2
Remove
Plan 3
Remove
Volume Simulation
Organ
7039.09 cc
Healthy tissue
7036.40 cc (90.03%)
Nodules
2.70 cc (0.04%)
Healthy tissue
7036.40 cc
6337.06 cc (90.03%)
Remaining part
702.04 cc (9.97%)
Resected part
Organ volume
7039.09 cc
6337.06 cc (90.03%)
Remaining part
702.04 cc (9.97%)
Resected part
Warning: Simulated Vascular Territories are computed from the selected network. The precision is then fully dependent of the native image quality.
720
Statistics
710
Identifier
Dr. Surry Jones
@Dr. Raymond Smith can you please take a look at this plan for a Resection? I am not sure if there is enough Healthy tissue remaining after the procedure.
Dr. Raymond Smith
@Dr. Surry Jones I looked at the simulation, I think it is perfectly fine. Here is a video of similar case, please review before proceeding:
Surgery Video
05-25-24.MOV
Kieron Stephenson
@Dr. Surry Jones How does the proximity of this tumor to critical structures impact the surgical plan?
Dr. Surry Jones
@Kieron Stephenson See this healthy tissue volume simulation
plan - Resection simulation
715
Telepresence
Content Feed

FIG. 7

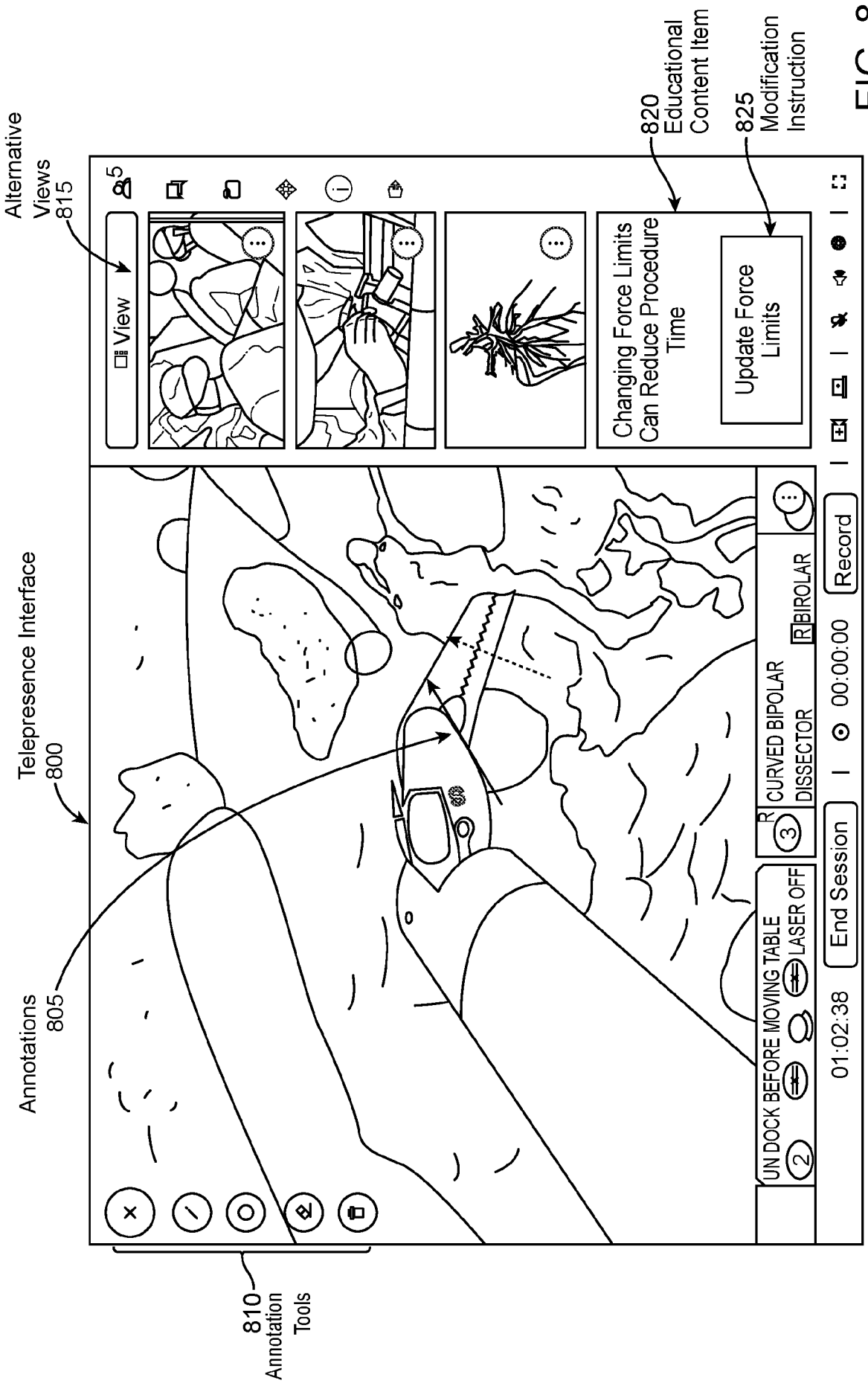
Alternative Views 815
Telepresence Interface 800
Annotations 805
810 Annotation Tools
820 Educational Content Item
825 Modification Instruction
View
Changing Force Limits Can Reduce Procedure Time
Update Force Limits
UN DOCK BEFORE MOVING TABLE
LASER OFF
CURVED BIPOLAR DISSECTOR
BIROLAR
01:02:38
End Session
00:00:00
Record

FIG. 8

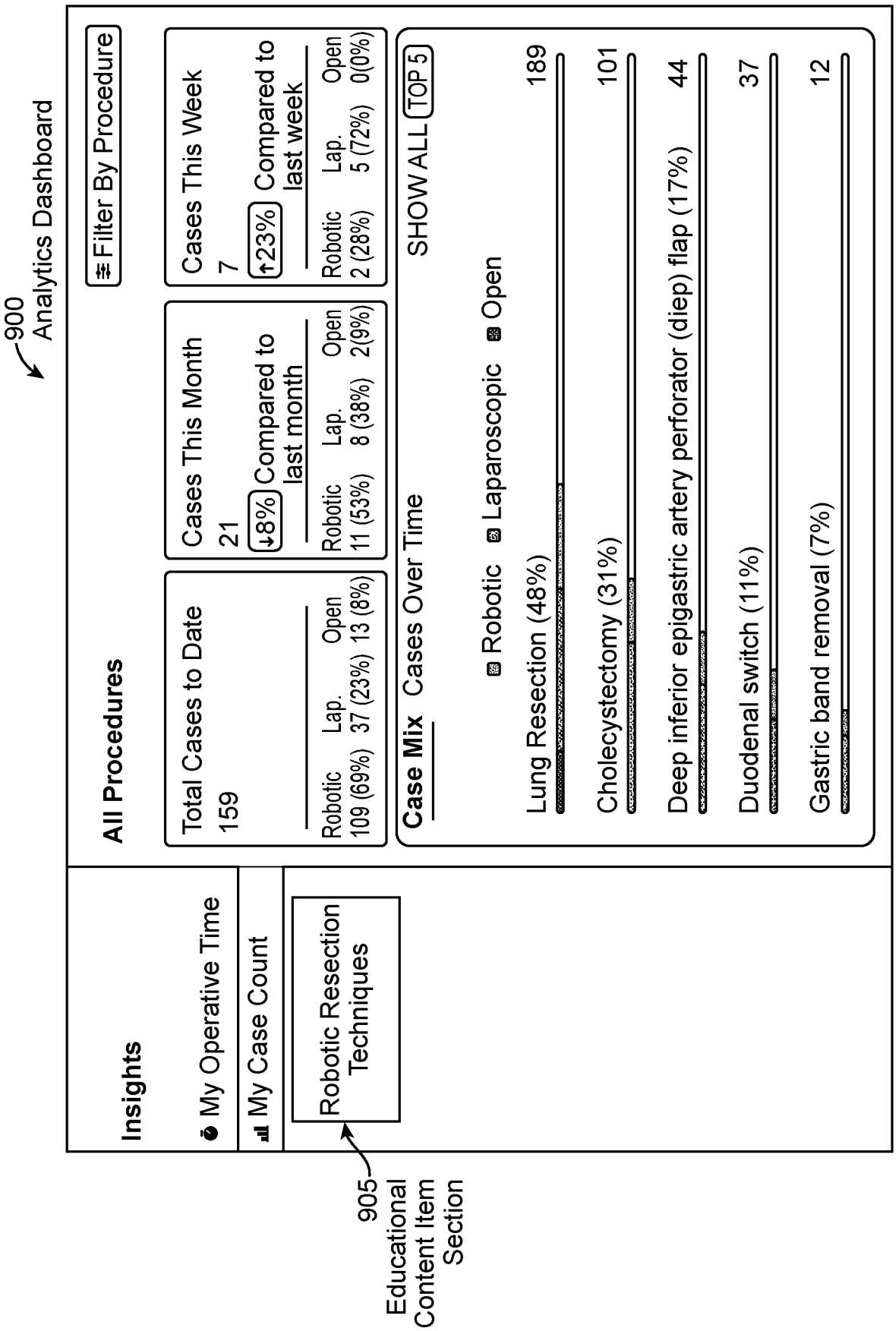
900
Analytics Dashboard
Insights
My Operative Time
My Case Count
Robotic Resection Techniques
905
Educational Content Item Section
All Procedures
Filter By Procedure
Total Cases to Date
159
Robotic Lap. Open
109 (69%) 37 (23%) 13 (8%)
Cases This Month
21
↓8% Compared to last month
Robotic Lap. Open
11 (53%) 8 (38%) 2(9%)
Cases This Week
7
↑23% Compared to last week
Robotic Lap. Open
2 (28%) 5 (72%) 0(0%)
Case Mix Cases Over Time
SHOW ALL TOP 5
Robotic Laparoscopic Open
Lung Resection (48%) 189
Cholecystectomy (31%) 101
Deep inferior epigastric artery perforator (diep) flap (17%) 44
Duodenal switch (11%) 37
Gastric band removal (7%) 12

FIG. 9

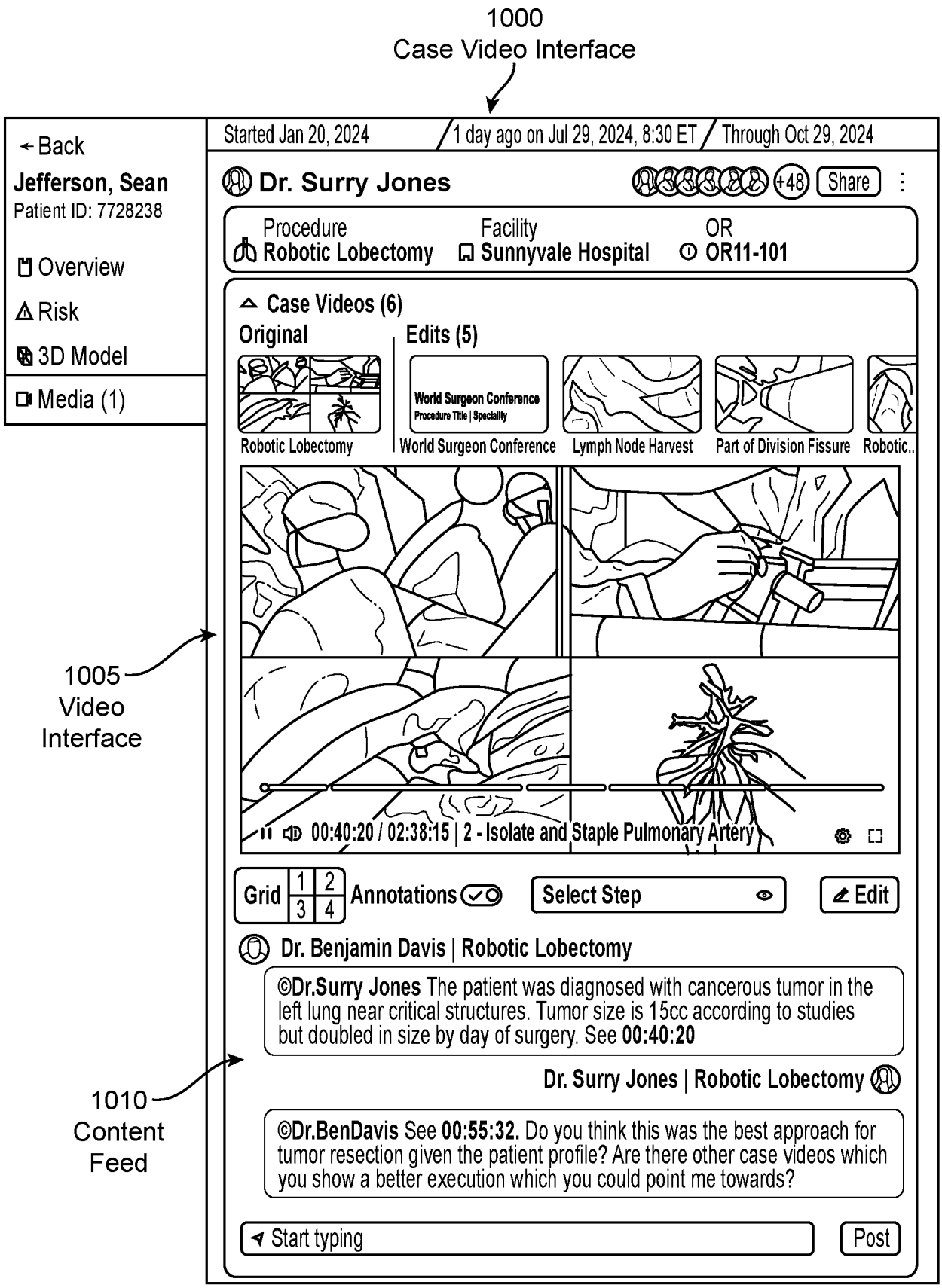
1000
Case Video Interface
Back
Jefferson, Sean
Patient ID: 7728238
Overview
Risk
3D Model
Media (1)
Started Jan 20, 2024
1 day ago on Jul 29, 2024, 8:30 ET
Through Oct 29, 2024
Dr. Surry Jones
+48
Share
Procedure
Robotic Lobectomy
Facility
Sunnyvale Hospital
OR
OR11-101
Case Videos (6)
Original
Edits (5)
Robotic Lobectomy
World Surgeon Conference
Procedure Title | Specialty
World Surgeon Conference
Lymph Node Harvest
Part of Division Fissure
Robotic...
1005
Video
Interface
00:40:20 / 02:38:15 | 2 - Isolate and Staple Pulmonary Artery
Grid
1
2
3
4
Annotations
Select Step
Edit
Dr. Benjamin Davis | Robotic Lobectomy
©Dr.Surry Jones The patient was diagnosed with cancerous tumor in the left lung near critical structures. Tumor size is 15cc according to studies but doubled in size by day of surgery. See 00:40:20
Dr. Surry Jones | Robotic Lobectomy
1010
Content
Feed
©Dr.BenDavis See 00:55:32. Do you think this was the best approach for tumor resection given the patient profile? Are there other case videos which you show a better execution which you could point me towards?
Start typing
Post

FIG. 10

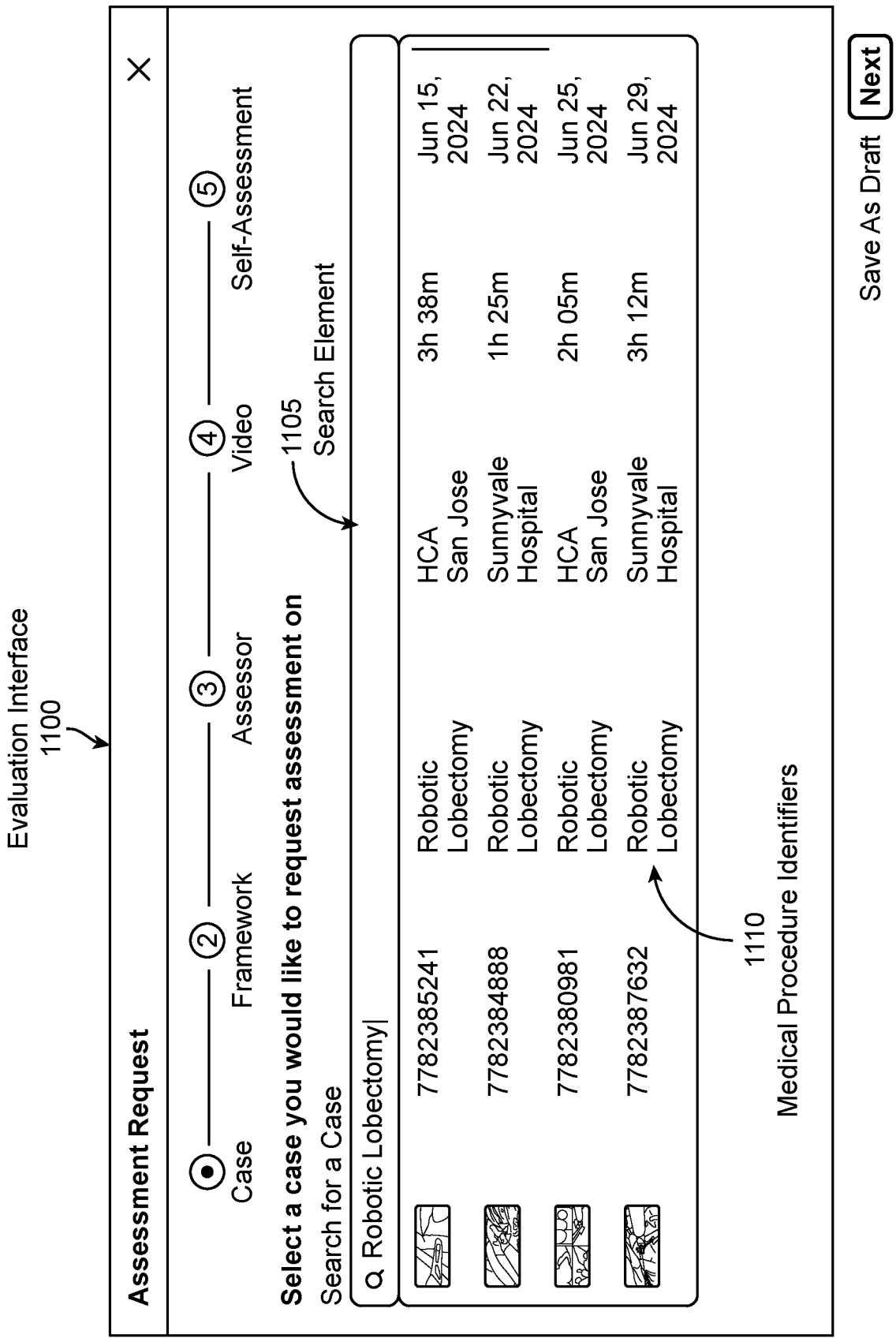
Evaluation Interface
1100
Assessment Request
1 Case
2 Framework
3 Assessor
4 Video
5 Self-Assessment
Select a case you would like to request assessment on
Search for a Case
Q Robotic Lobectomy|
1105
Search Element
7782385241
Robotic Lobectomy
HCA San Jose
3h 38m
Jun 15, 2024
7782384888
Robotic Lobectomy
Sunnyvale Hospital
1h 25m
Jun 22, 2024
7782380981
Robotic Lobectomy
HCA San Jose
2h 05m
Jun 25, 2024
7782387632
Robotic Lobectomy
Sunnyvale Hospital
3h 12m
Jun 29, 2024
1110
Medical Procedure Identifiers
Save As Draft
Next

FIG. 11

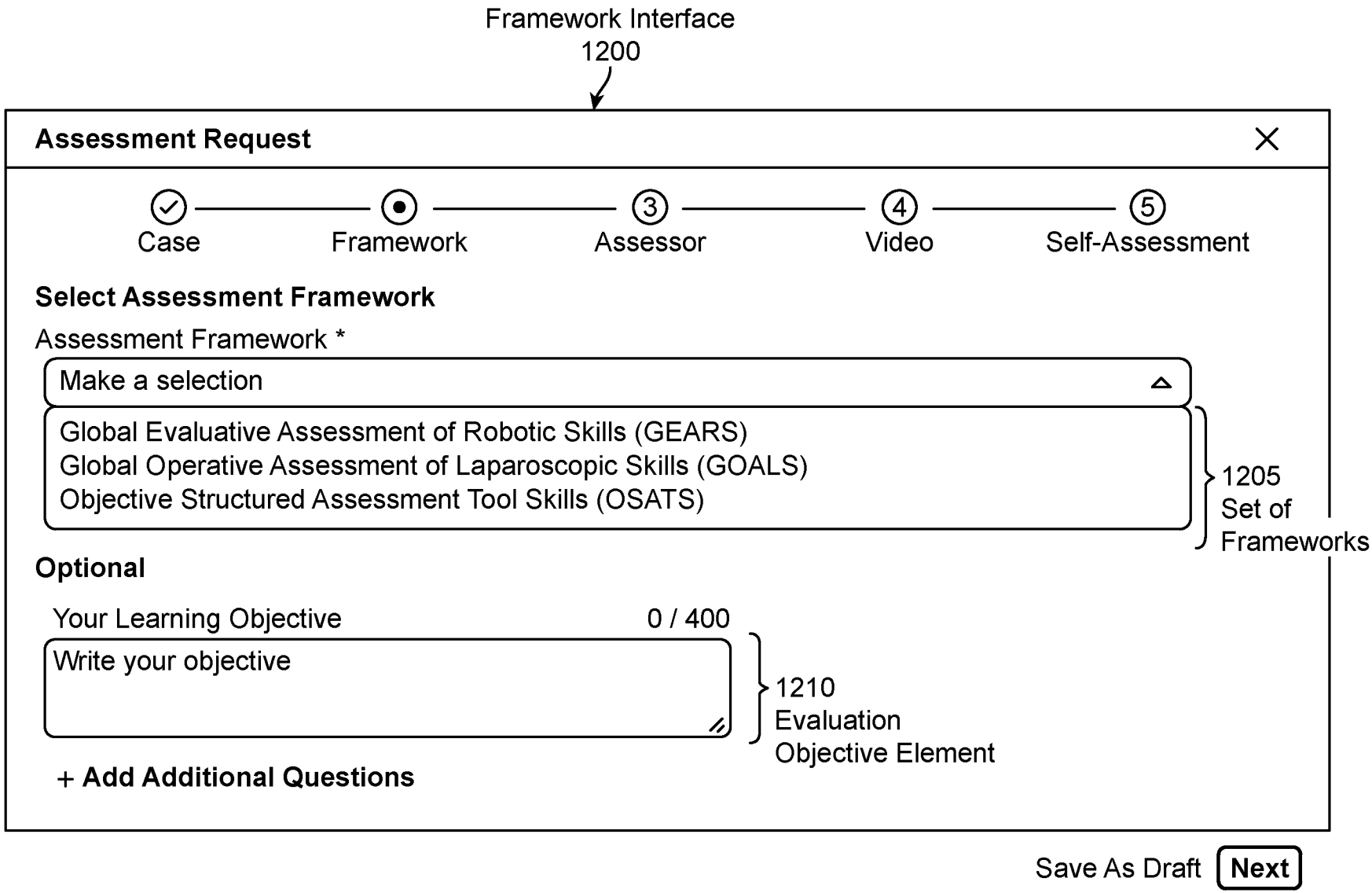
Framework Interface
1200
Assessment Request
Case
Framework
3
Assessor
4
Video
5
Self-Assessment
Select Assessment Framework
Assessment Framework *
Make a selection
Global Evaluative Assessment of Robotic Skills (GEARS)
Global Operative Assessment of Laparoscopic Skills (GOALS)
Objective Structured Assessment Tool Skills (OSATS)
1205
Set of
Frameworks
Optional
Your Learning Objective
0 / 400
Write your objective
1210
Evaluation
Objective Element
+ Add Additional Questions
Save As Draft
Next

FIG. 12

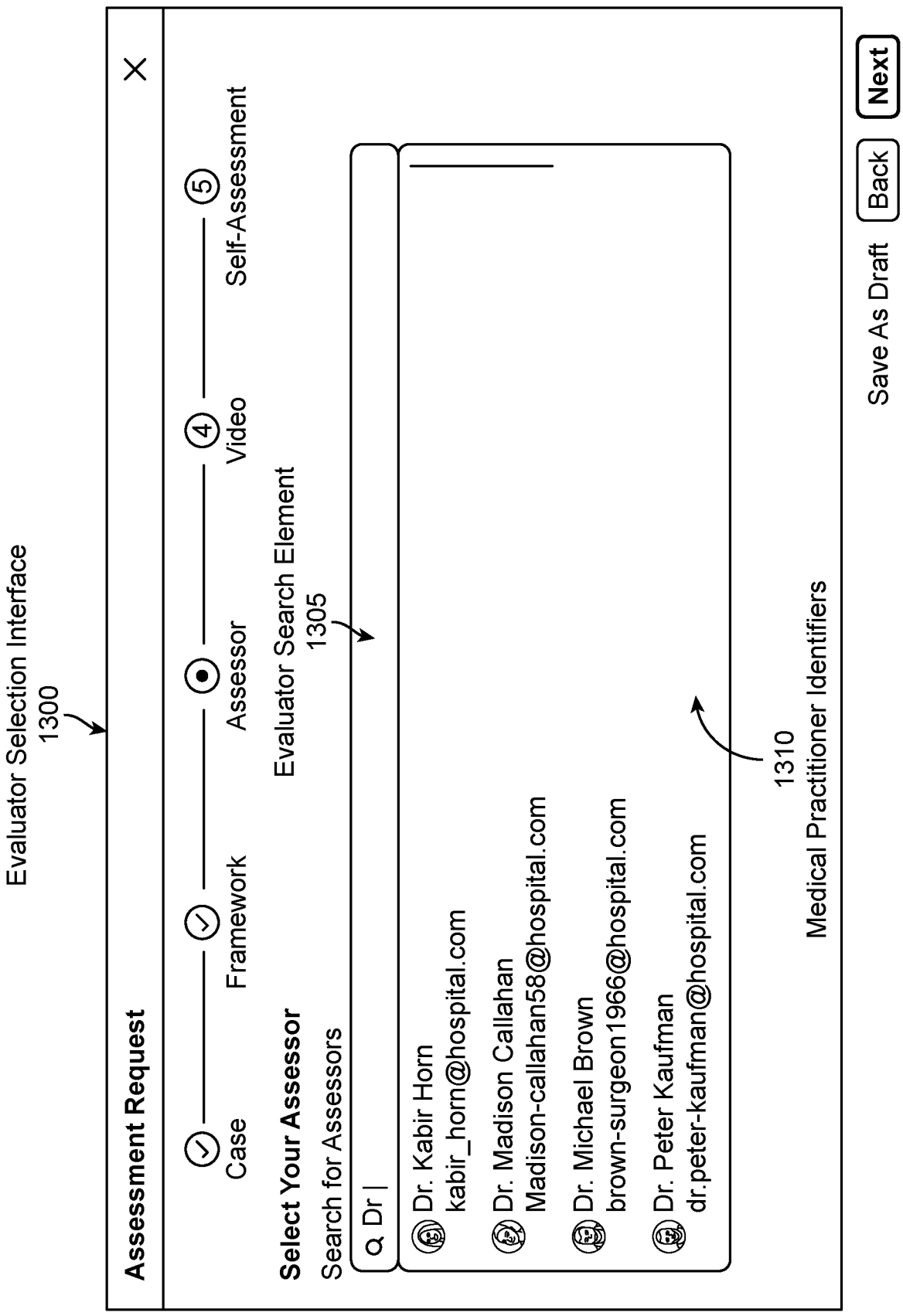
Evaluator Selection Interface
1300
Assessment Request
Case
Framework
Assessor
Video
Self-Assessment
Select Your Assessor
Search for Assessors
Evaluator Search Element
1305
Q Dr |
Dr. Kabir Horn
kabir_horn@hospital.com
Dr. Madison Callahan
Madison-callahan58@hospital.com
Dr. Michael Brown
brown-surgeon1966@hospital.com
Dr. Peter Kaufman
dr.peter-kaufman@hospital.com
1310
Medical Practitioner Identifiers
Save As Draft
Back
Next

FIG. 13

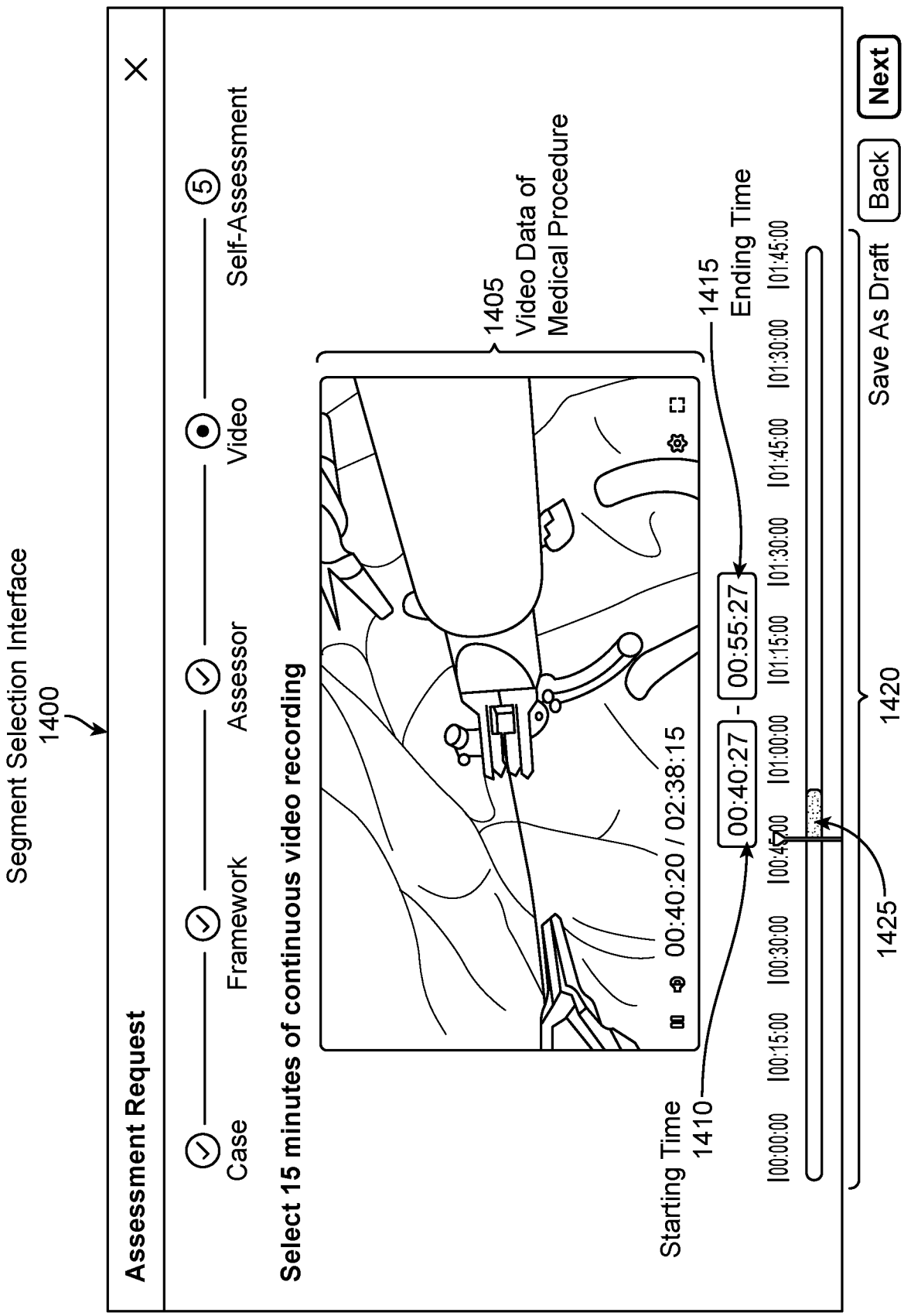
Segment Selection Interface
1400
Assessment Request
Case
Framework
Assessor
Video
Self-Assessment
Select 15 minutes of continuous video recording
1405
Video Data of Medical Procedure
1415
Ending Time
00:40:20 / 02:38:15
Starting Time
1410
00:40:27
00:55:27
00:00:00
00:15:00
00:30:00
00:45:00
01:00:00
01:15:00
01:30:00
01:45:00
Save As Draft
Back
Next
1420
Video Data Timeline
1425
Segment Identifier

FIG. 14

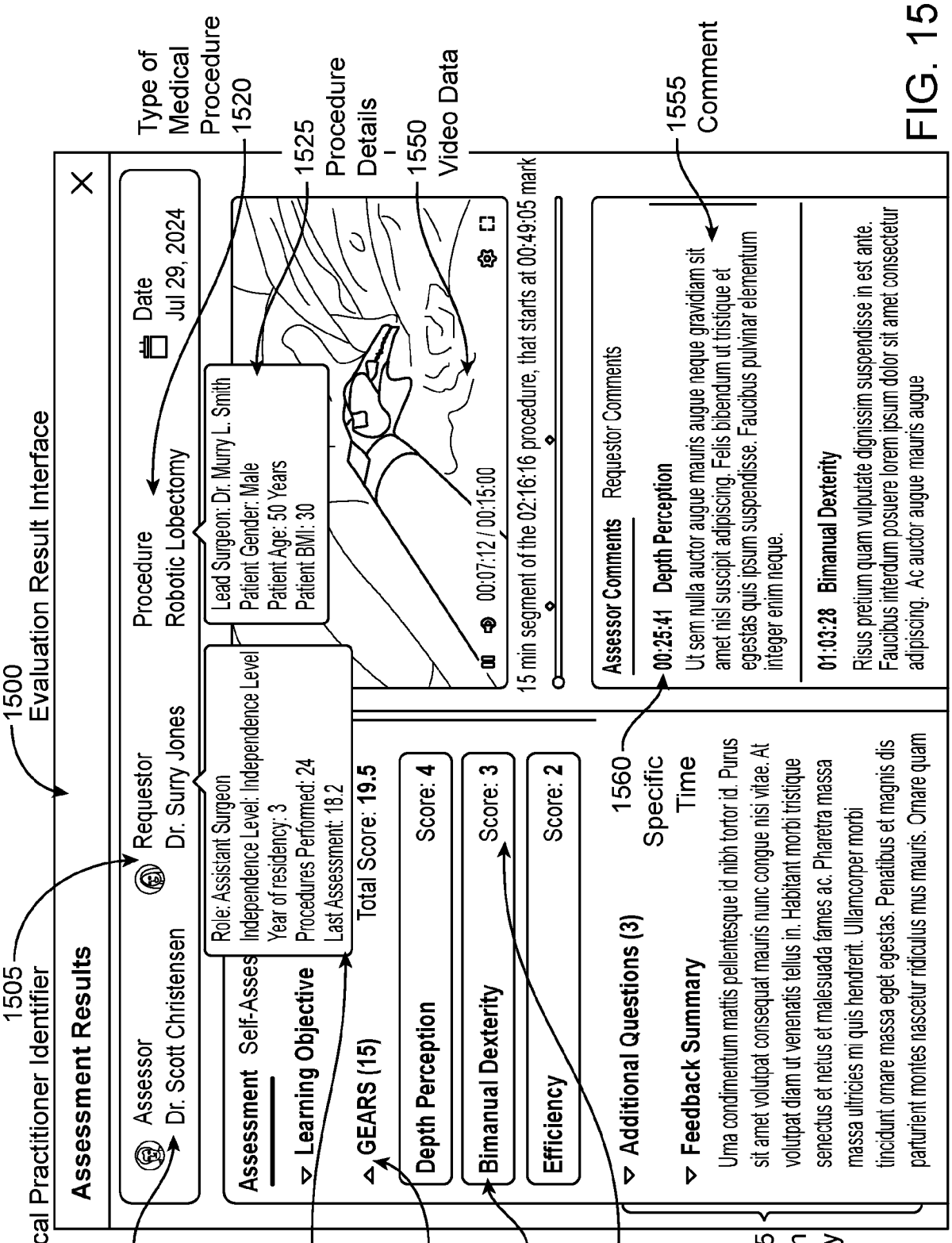
1500 Evaluation Result Interface
1505 Medical Practitioner Identifier
Assessment Results
Assessor Dr. Scott Christensen
Requestor Dr. Surry Jones
Date Jul 29, 2024
Procedure Robotic Lobectomy
Type of Medical Procedure 1520
1525 Procedure Details
1550 Video Data
1555 Comment
Lead Surgeon: Dr. Murry L. Smith
Patient Gender: Male
Patient Age: 50 Years
Patient BMI: 30
Role: Assistant Surgeon
Independence Level: Independence Level
Year of residency: 3
Procedures Performed: 24
Last Assessment: 18.2
00:07:12 / 00:15:00
15 min segment of the 02:16:16 procedure, that starts at 00:49:05 mark
Assessment Self-Asses
Learning Objective
GEARS (15) Total Score: 19.5
Depth Perception Score: 4
Bimanual Dexterity Score: 3
Efficiency Score: 2
Additional Questions (3)
Feedback Summary
Assessor Comments Requestor Comments
00:25:41 Depth Perception
Ut sem nulla auctor augue mauris augue neque gravidiam sit amet nisl suscipit adipiscing. Felis bibendum ut tristique et egestas quis ipsum suspendisse. Faucibus pulvinar elementum integer enim neque.
01:03:28 Bimanual Dexterity
Risus pretium quam vulputate dignissim suspendisse in est ante. Faucibus interdum posuere lorem ipsum dolor sit amet consectetur adipiscing. Ac auctor augue mauris augue
Uma condimentum mattis pellentesque id nibh tortor id. Purus sit amet volutpat consequat mauris nunc congue nisi vitae. At volutpat diam ut venenatis tellus in. Habitant morbi tristique senectus et netus et malesuada fames ac. Pharetra massa massa ultricies mi quis hendrerit. Ullamcorper morbi tincidunt ornare massa eget egestas. Penatibus et magnis dis parturient montes nascetur ridiculus mus mauris. Ornare quam
1515 Evaluating Medical Practitioner Identifier
1510 Medical Practitioner Information
1530 Framework Identifier
1535 Category
1540 Evaluation Value
1560 Specific Time
1545 Evaluation Summary

FIG. 15

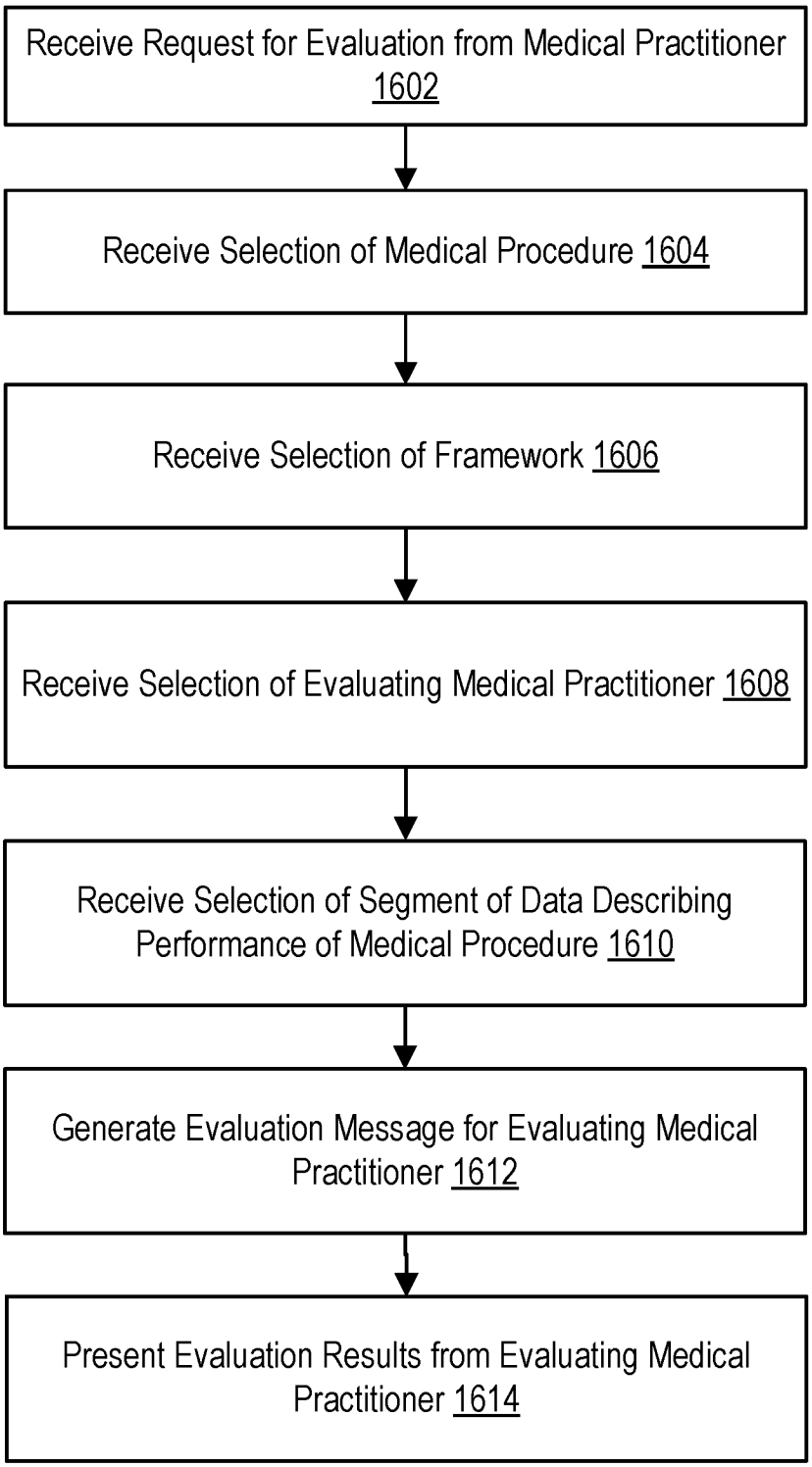
Receive Request for Evaluation from Medical Practitioner 1602
Receive Selection of Medical Procedure 1604
Receive Selection of Framework 1606
Receive Selection of Evaluating Medical Practitioner 1608
Receive Selection of Segment of Data Describing Performance of Medical Procedure 1610
Generate Evaluation Message for Evaluating Medical Practitioner 1612
Present Evaluation Results from Evaluating Medical Practitioner 1614

FIG. 16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2024/062183

A. CLASSIFICATION OF SUBJECT MATTER

G16H 40/20(2018.01)i; **G06Q 10/06**(2012.01)i; **G06Q 50/20**(2012.01)i; **G06Q 50/10**(2012.01)i; **G06N 3/0985**(2023.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G16H 40/20(2018.01); A61B 34/10(2016.01); A61B 5/00(2006.01); A61B 90/00(2016.01); G06N 20/00(2019.01); G16H 20/40(2018.01); G16H 50/20(2018.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: evaluate, surgery, education, video, colleague, collaborate

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2019-536132 A (TERARECON INC.) 12 December 2019 (2019-12-12) See paragraphs 18, 26, 120, 149-151 and claim 10.	1-20
Y	US 2023-0172684 A1 (GENESIS MEDTECH (USA) INC.) 08 June 2023 (2023-06-08) See paragraphs 34, 47 and claim 1.	1-20
Y	JP 2021-191519 A (INTUITIVE SURGICAL OPERATIONS INC.) 16 December 2021 (2021-12-16) See paragraphs 86, 98 and claims 1, 7.	2-6,10-14,17-20
Y	US 2020-0350063 A1 (IMAGE STREAM MEDICAL, INC.) 05 November 2020 (2020-11-05) See paragraphs 52, 56 and claim 1.	5,13,17-20
A	KR 10-2023-0113600 A (INTUITIVE SURGICAL OPERATIONS INC.) 31 July 2023 (2023-07-31) See claims 1, 10.	1-20

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 March 2025	**23 March 2025**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office **189 Cheongsa-ro, Seo-gu, Daejeon** **35208, Republic of Korea**	**LEE, Kang Ha**
Facsimile No. **+82-42-481-8578**	Telephone No. **+82-42-481-8463**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2024/062183

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2019-536132 A	12 December 2019	AU 2017-342283 A1	11 April 2019
		CA 3038848 A1	19 April 2018
		EP 3526730 A1	21 August 2019
		KR 10-2019-0071724 A	24 June 2019
		US 10445462 B2	15 October 2019
		US 10970365 B2	06 April 2021
		US 2018-0101645 A1	12 April 2018
		US 2019-0392942 A1	26 December 2019
		WO 2018-071575 A1	19 April 2018
US 2023-0172684 A1	08 June 2023	WO 2023-107394 A1	15 June 2023
JP 2021-191519 A	16 December 2021	CN 108472084 A	31 August 2018
		CN 108472084 B	27 August 2021
		CN 113456241 A	01 October 2021
		EP 3373834 A1	19 September 2018
		JP 2018-538037 A	27 December 2018
		JP 2023-126480 A	07 September 2023
		JP 7608305 B2	06 January 2025
		KR 10-2018-0068336 A	21 June 2018
		US 10912619 B2	09 February 2021
		US 11751957 B2	12 September 2023
		US 12114949 B2	15 October 2024
		US 2019-0090969 A1	28 March 2019
		US 2021-0186634 A1	24 June 2021
		US 2024-0115333 A1	11 April 2024
		WO 2017-083768 A1	18 May 2017
US 2020-0350063 A1	05 November 2020	US 11557392 B2	17 January 2023
		US 11783193 B2	10 October 2023
		US 2023-0117254 A1	20 April 2023
		WO 2020-227128 A1	12 November 2020
KR 10-2023-0113600 A	31 July 2023	CN 116711019 A	05 September 2023
		EP 4256579 A1	11 October 2023
		JP 2023-552201 A	14 December 2023
		US 2023-0317258 A1	05 October 2023
		WO 2022-119754 A1	09 June 2022