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(54) Title: NEUROTRANSMISSION MEASUREMENT ADAPTER

(57) Abstract: An apparatus and method for use in determining a neuromuscular transmission value for a patient is provided. The apparatus includes a cuff for receiving a thumb of a patient therein and an accelerometer positioned on the cuff at substantially a tip of the thumb. A support member is coupled to the cuff and maintains the thumb in a predetermined position and restricts movement of the thumb. A stimulation mechanism applies a stimulus to a nerve. In response to the applied stimulus, the thumb is caused to move and exert a force on the support member sufficient to overcome the restricted movement. The accelerometer generates an electrical signal indicative of movement of the thumb for use in determining a neuromuscular transmission value indicative of a level of muscular paralysis.

FIG. 1
Neurotransmission Measurement Adapter

Field of the Invention

This invention concerns an apparatus and method for patient monitoring devices and, more specifically, for measuring neuromuscular transmission in a patient undergoing a medical procedure to ensure the patient is properly anesthetized and to determine the level of residual effects of anesthesia after the completion of the medical procedure.

Background of the Invention

In the course of providing healthcare to patients, certain procedures require administering anesthesia to the patient in order to render the patient insensitive to any pain associated with the procedure. A patient may be subjected to local anesthesia whereby an anesthetic is introduced at a location on the patient where the procedure is to be performed. Such anesthesia is commonly used, for example, when a patient is receiving stitches. However, other procedures are significantly more complex and result in systemic pain that, if untreated, would be intolerable to the patient. Moreover, these procedures may cause muscular response by the patient which may disrupt or otherwise prevent the healthcare professional from completing the procedure. Patients are often put under general anesthesia which requires the administration of neuromuscular blocking agents (NMBA's) that result in muscle relaxation and respiratory paralysis. Thus, endotracheal intubation is necessary to facilitate mechanical breathing (e.g. ventilation) during the procedure. In this state, spontaneous breathing is prevented and the patient is pharmacologically restrained to prevent injury to themselves. The effect and level of relaxation achieved by using the NMBA's is important from a monitoring standpoint. Quantitative monitoring of the depth of anesthesia helps determine the degree of paralysis, manage the level of blockage of neuromuscular transmission and optimize the amount of drugs administered during the procedure. One manner of quantitatively monitoring the effect of NMBA's is acceleromyography (AMG) which employs an impulse to stimulate a nerve for a particular digit on the patient's hand causing the digit to move. An accelerometer quantifies the muscle response by converting the physical motion to an electrical signal. However, the accelerometers in conventionally available AMG monitoring systems provide
inaccurate results due to their positioning on the patient. Additionally, neural stimulation may not cause a sufficient neuromuscular response that would enable conventional AMG monitoring systems to effectively monitor the patient during the procedure. A system according to invention principles addresses deficiencies of known systems.

**Summary of the Invention**

In one embodiment, an apparatus for use in determining a neuromuscular transmission value for a patient is provided. The apparatus includes a cuff for receiving a thumb of a patient therein and an accelerometer positioned on the cuff at substantially a tip of the thumb. A support member is coupled to the cuff and maintains the thumb in a predetermined position and restricts movement of the thumb. A stimulation mechanism applies a stimulus to a nerve. In response to the applied stimulus, the thumb is caused to move and exert a force on the support member sufficient to overcome the restricted movement. The accelerometer generates an electrical signal indicative of movement of the thumb for use in determining a neuromuscular transmission value.

In another embodiment, a method of determining a neuromuscular transmission value for a patient is provided. The method includes retaining an accelerometer at tip of a thumb of the patient and supporting the thumb of the patient using a support member to maintain the thumb in a predetermined position and restrict movement of the thumb from the predetermined position. A stimulus is applied to a nerve of a patient causing the thumb to exert a force on the support member and move from the predetermined position. The movement of the thumb from the predetermined position is measured using the accelerometer and a neuromuscular transmission value for the patient is determined using the measured movement of the thumb.

In a further embodiment, a system for identifying a neuromuscular transmission value is provided. The system includes an adapter selectively positionable on the palm of a user’s hand that supports a thumb in a predetermined position and restricts movement of the thumb. The adapter includes an accelerometer positioned on the adapter at substantially a tip of the thumb and a stimulation mechanism positioned that applies a stimulus to a nerve that causes the thumb to move from the predetermined position in a direction towards a palm
of the hand, wherein the accelerometer generates an electrical signal including data indicative of movement of the thumb. A measurement device calculates a neuromuscular transmission value associated with a patient. The measurement device includes a control processor coupled to the stimulation mechanism that signals the stimulation mechanism to apply the stimulus to the nerve. A measurement processor is coupled to the accelerometer and receives the electrical signal indicative of thumb movement from the accelerometer and calculates the neuromuscular transmission value for the patient using thumb movement data. A communication processor is coupled to the measurement processor and communicates the calculated neurotransmission value to a healthcare professional.

A further embodiment includes a method of identifying a neurotransmission value of a patient. The method includes the activities of positioning an adapter on a hand of a patient to support a thumb in a predetermined position and restrict movement of the thumb. The adapter includes an accelerometer positioned on the adapter at substantially a tip of the thumb. A stimulation mechanism applies a stimulus to a nerve of the patient causing the thumb to move from the predetermined position in a direction towards a palm of the hand in response to a control signal generated by a control processor. An electrical signal including data indicative of movement of the thumb by the accelerometer is generated and received by a measurement processor. The electrical signal is indicative of thumb movement sensed by the accelerometer. The neuromuscular transmission value for the patient is calculated using thumb movement data. Data representing the neuromuscular transmission value for the patient is communicated to a healthcare professional.

Brief Description of the Drawings

Figure 1 depicts a perspective view of a first embodiment of the NMT measurement apparatus according to invention principles positioned on a hand of a user;

Figure 2 depicts a top view of the first embodiment of the NMT measurement apparatus according to invention principles positioned on a hand of a user;
Figure 3 depicts a perspective view of the first embodiment of the NMT measurement apparatus according to invention principles positioned on a hand of a user;

Figure 4 depicts a top side view of a second embodiment of the NMT measurement apparatus according to invention principles positioned on a hand of a user;

Figure 5 depicts a perspective view of a third embodiment of the NMT measurement apparatus according to invention principles positioned on a hand of a user;

Figure 6 depicts a top view of the third embodiment of the NMT measurement apparatus according to invention principles positioned on a hand of a user;

Figure 7 depicts a perspective view of the third embodiment of the NMT measurement apparatus according to invention principles positioned on a hand of a user;

Figure 8 depicts a perspective view of a fourth embodiment of the NMT measurement apparatus according to invention principles positioned on a hand of a user;

Figure 9 depicts a perspective view of the fourth embodiment of the NMT measurement apparatus according to invention principles positioned on a hand of a user;

Figure 10 is an exemplary block diagram of an NMT monitoring system according to invention principles;

Figure 11 is a flow diagram detailing operation of the NMT measurement apparatus according to invention principles;

Figure 12 is a flow diagram detailing operation of the NMT monitoring system according to invention principles.

**Detailed Description**

An apparatus and system for measuring neuromuscular transmission (NMT) of a patient is provided. In one embodiment, the apparatus and system may be used to measure the NMT of a patient that is under the effects of a neuromuscular blocking agent (NMBA) is provided. The NMT measurement apparatus allows a healthcare professional to monitor and determine the depth of
anesthesia when patient is undergoing a medical procedure and residues of anesthesia in patient remain after the completion of the medial procedure, by selectively measuring a neuromuscular response to an electrical stimuli that is applied to the peripheral nerve. The NMT measurement apparatus includes an adapter that is selectively positionable on at least a thumb of a user. The adapter includes a first section. The first section of the adapter advantageously automatically pre-loads the thumb into a first position such that an angle between the thumb and pointer finger is maintained within a predetermined range. Additionally, the adapter is formed to ensure and facilitate the natural opposable movement of the thumb and does not constrain the movement of the thumb in any direction other than the natural movement path. In doing so, the adapter advantageously ensures that, in response to any neuromuscular stimulation, the thumb will move in a direction towards the little finger (e.g. pinky) and/or ring finger on the patient's hand. The adapter includes an accelerometer positioned substantially at a tip of the thumb on the palm side thereof. The positioning of the accelerometer advantageously enables the system to obtain a higher amplitude acceleration measurement when the electrical stimuli is applied to the nerve causing the thumb of the patient to move towards the pinky and ring finger. By obtaining a higher amplitude acceleration measurement, the NMT measurement system is able to convert the higher amplitude physical motion into an electrical signal thereby advantageously generating a more accurate measurement of neuromuscular transmission while under anesthesia.

A temperature sensor may be selectively positioned on the adapter at substantially a heel of the thumb. The temperature sensor periodically senses the temperature of the patient. The sensed temperature corresponds to an amount of blood flow to the palm and the thumb enabling the healthcare practitioner to be able to monitoring a temperature value of the palm in real time. The real time temperature monitoring at the palm makes certain there has been no blood flow restrictions to the palm thereby advantageously enabling the system to determine if movement sensed by the accelerometer is associated with a neuromuscular response caused by stimulation of the nerve. In this embodiment, the temperature value sensed by the temperature sensor may be used to automatically modify the type and duration of the electrical stimuli that is applied to the patient if the sensed temperature value is outside a predetermined threshold temperature range.
In another embodiment, the adapter further includes a second section that is selectively positioned on at least one of the ring finger and pinky finger of the patient. The second section may be positioned on the intermediate phalanges of the respective ring and little fingers and includes a second accelerometer. The inclusion of a second accelerometer advantageously enables the NMT measurement system to obtain a second measurement associated with neuromuscular transmission. This second NMT measurement value is advantageous because, at times, stimulation of the peripheral nerve may not result in movement of the thumb. Instead, stimulation of the peripheral nerve may cause at least one of the little finger and ring finger to twitch and move in a direction towards the palm of the hand. Thus, the NMT measurement system automatically measures the acceleration (e.g. physical movement) of both the thumb and the little finger/ring finger to determine the depth of anesthesia including the effectiveness of the NMBA’s on the patient.

A connector connects the first section of the adapter (e.g. thumb section) with the second section (e.g. little finger/pinky section). The connector may also advantageously pre-load the thumb in the first position and function as a guide to facilitate the natural opposable movement of the thumb when electrical stimuli is applied to the nerve. The connector may also pre-load the ring and little fingers to maintain them in a static position until such time that the peripheral nerve is stimulated by electrical stimuli.

Thus, the NMT measurement system advantageously calculates and determines an NMT measurement value associated with a depth of anesthesia for a particular patient. The system causes the peripheral nerve to be stimulated in a predetermined pattern and automatically converts any physical motion of the thumb, ring and little finger into respective electrical signals to quantify the neuromuscular response to the stimuli. The NMT measurement system also advantageously uses a temperature of the skin sensed by the temperature sensor to automatically determine if the quantified neuromuscular response is valid by identifying an amount of blood flowing to the thumb. The NMT measurement system automatically compares the neuromuscular response value to a threshold to determine the effectiveness of the NMBA on the patient. By determining the effectiveness of the NMBA a healthcare profession can determine if more or less
NMBA is to be administered based on when during the procedure the neuromuscular response value is derived.

In another embodiment, the apparatus and system may be used to measure the NMT value for a patient to determine if there is neural connectivity for the patient at a given time. For example, in the case of a transplant or re-attachment of a body part, the apparatus and system may be used to determine neuromuscular activity in the patient to identify a level of success in reconnecting nerve tissue. The above described aspects of the apparatus and system for measuring an NMT value may be applied in this embodiment as well. In a further embodiment, the determined NMT value may be indicative of a level of muscular paralysis of a patient.

Figure 1 is a perspective view of an exemplary embodiment of the NMT adapter 100 positioned on a hand 2 of a user. The adapter 100 includes a first section 104 that selectively receives a thumb 4 of a user therein. The first section 104 may be a cuff. The first section 104 is shown herein as completely covering the thumb 4 of the user. In another embodiment, the first section 104 may have an aperture at a tip end thereof enabling at least a part of the tip of the thumb to remain uncovered and exposed. The first section 104 includes a first accelerometer 106 positioned at substantially a tip end of the thumb on the palm side thereof. The first section 104 may be formed from a thin, lightweight, flexible material that is breathable to allow the skin of the thumb 4 covered by the first section 104 to breathe. In one embodiment, the material from which the first section 104 is formed may be an elastomer or polymer material having a plurality of apertures extending therethrough enabling air to flow and allowing the skin of the thumb to breathe. Thus, the material may be semi-permeable and/or porous.

The adapter 100 further includes a second section 102 that functions as a support section supporting the thumb 4 in a first pre-determined pre-loaded position. The second section 2 begins at substantially a base of the thumb and extends over and around the hand 2 to at least partially cover a palm 7 of the hand 2 and also covers a corresponding portion of the dorsal side of the hand 2 (not shown). In this embodiment, the second section 102 extends and covers a heel 6 of the thumb 4 on the palm side and a corresponding area on the dorsal side of the hand 2 (not shown). For example, the second section 102 may cover an area of the palm 7 and corresponding dorsal section of the hand 4 that includes the metatarsal
of the thumb 4. The second section 102 releasbly secures the adapter 100 to the hand 2 of the user such that the adapter 100 will remain in place on the user's hand regardless of the position of the user. For example, the second section 102 of the adapter should secure the position of the adapter if the user is positioned face up resulting in the hand being supported by a surface or if the user is face down requiring that the hand of the user dangle over an edge of a surface that is supporting the patient (e.g. during a surgical procedure on a user's back).

The second section 102 (e.g. support section) is formed from a semi-rigid material that is able to maintain the thumb 4 in a first pre-loaded position. In one embodiment, the material that forms the second section 102 has a thickness greater than the material that forms the first section 104. Thus, the material forming the second section 102 may also be an elastomer that exerts a force on the thumb 4 and biases the thumb 4 into the first pre-loaded position. In another embodiment, the material that forms the second section 102 may also include a plurality of apertures making the section 102 semi-permeable to enable the skin on which it is positioned to breathe. By pre-loading the thumb in a first position, the adapter advantageously causes the thumb 4 to be maintained in a same position relative to the pointer finger 5 and palm 7 of the hand when at rest (e.g. not stimulated). In one embodiment, the adapter may pre-load the thumb in the first position maintaining an angle between the thumb 4 and pointer finger 5 with a range substantially between 45 degrees and 90 degrees. The angle maintained between the thumb 4 and pointer finger 5 is described for purposes of example only and the adapter may pre-load the thumb 4 to form any angle between the thumb 4 and pointer finger 5. By maintaining the thumb 4 in a consistent initial first position during a time period which NMT measurements are being taken advantageously enables an improved measure of NMT. The adapter 100 facilitates an improved NMT measurement because the thumb, in the first position, presents a consistent starting point from which any acceleration of the thumb is measured in response to electrical stimulation of the peripheral (e.g. ulnar) nerve. Additionally, while the material from which the second section 102 is formed is semi-rigid, the material should not inhibit the natural opposable movement of the thumb. Rather, the semi-rigid material from which the second section 102 is formed, guides or otherwise facilitates the natural opposable movement of the thumb towards a little finger 10 and ring finger 8 of the hand 2. By facilitating the
natural opposable movement of the thumb, any acceleration measured by the accelerometer 106 during movement of the thumb has a higher amplitude and provides a more precise and more easily quantifiable metric for measuring NMT in response to nerve stimulation. In one embodiment, a point at which the second section 102 meets the first section 104 is substantially between the metacarpophalangeal joint and the interphalangeal joint of the thumb. In this manner, the semi-rigid material of the second section 102 is able to provide sufficient force to pre-load the thumb into the predetermined first position. In another embodiment, the point at which the second section 102 joins the first section 104 is at the metacarpophalangeal joint which may also exert a sufficient force on the thumb 4 to maintain the thumb 4 in a pre-loaded first position.

The second section 102 may also include a temperature sensor 108 that is positioned substantially on the heel 6 of the thumb 4 (e.g. over the metacarpal of the thumb). The second section 102 ensures that the temperature sensor 108 contacts the skin on the heel 6 of the thumb 4. By maintaining the temperature sensor 108 in a constant position substantially on the heel 6 of the thumb 4, the adapter 100 advantageously ensures an accurate temperature reading because the temperature sensor 108 is positioned over an area that includes a high concentration of blood vessels that circulate blood to and from the thumb 4. The temperature sensor 108 automatically senses a temperature of the skin at predetermined time periods for use in determining if blood flow to the thumb 4 is sufficient. As will be discussed hereinafter, the temperature measurement taken by the temperature sensor 108 advantageously serves as a check to determine if one of (a) movement of the thumb or (b) lack of movement of the thumb, in response to neural stimulation, is the result of the NMBA's or might be caused because there is an insufficient amount of blood flowing to the thumb 4 thereby hindering the reflex response of the thumb. In one embodiment, the temperature sensor 108 is a thermistor that senses the temperature of the skin.

A cable 111 connects the adapter 100 to a monitoring device (see Fig. 10, Ref No. 1008 and/or 1018). As shown in Figure 10, the monitoring device may be a stand-alone device that is able to receive data from sensors and calculate a neurotransmission measurement value (1008 in Fig. 10). Alternatively, the calculation of a neurotransmission value may be performed by a patient monitoring device (1018 in Fig. 10). The cable 111 includes at least two
electrodes 110 positioned substantially over the peripheral (e.g. ulnar) nerve. The cable 111 also includes a first connection wire 107 that couples the first accelerometer 106 to the monitoring device and enables acceleration data sensed by the first accelerometer 106 to be transmitted to the monitoring device for use in determining a neuromuscular transmission measurement value. The cable 111 also includes a second connection wire 109 that couples the temperature sensor 108 to the monitoring device. The second connection wire 109 enables temperature data representing a skin temperature of a user to be transmitted to the monitoring device. The temperature data is used to determine if the value sensed by the accelerometer is valid by detecting if the flow of blood through the thumb is of a sufficient rate. In one embodiment, the first and second connection wires 107,109 are free flowing wires that are positioned atop of the respective first and second sections 104, 102. In another embodiment, the adapter 100 may include respective wire channels formed therein that guide respective wires 107, 109 along a predetermined path over the hand 2 of the user whereby the wires 107, 109 meet at a junction point. At the junction point, the wires 107, 109 may run substantially adjacent one another along a length of the cable 111 to connect to an input of the monitoring device. The monitoring device is able to receive and process any data (e.g. acceleration data and/or temperature data) being transmitted via wires 107, 109 to determine the effectiveness of anesthesia on the patient by calculating a value corresponding to the neuromuscular transmission amount of NMT value.

In operation, the monitoring device causes the electrodes 110 to stimulate the peripheral nerve over which they are positioned. Stimulation of the peripheral nerve causes a reflex response in the user whereby at least the thumb 4 is caused to move in a direction indicated by the arrow labeled with reference numeral 112. The direction of movement 112 is toward the palm 7 and in a trajectory towards the ring finger 8 and little finger 10 of the hand 2. In response to the thumb 4 moving in direction 112, the first accelerometer 106 automatically senses the acceleration of the thumb 4 and converts the physical motion of the thumb movement into an electrical data signal representing the sensed movement of the thumb 4. The data signal representing the thumb movement sensed by the accelerometer 106 is communicated via first wire 107 through cable 111 and is received by the monitoring device. Additionally, the temperature sensor 108 may sense a skin temperature of the user. Data representing the sensed skin
temperature representing an amount of blood flow to and from the thumb 4 is transmitted via second wire 109 through cable 111 for receipt by the monitoring device. As will be discussed hereinafter with respect to Figures 10 - 12, the monitoring device uses the acceleration data and the temperature data as inputs for an algorithm to determine a value corresponding to the neuromuscular transmission for the user.

In one embodiment, the electrodes are caused, by the monitoring device, to stimulate the peripheral nerve in a predetermined pattern. The predetermined stimulation pattern may include any of (a) a single stimulation pulse; (b) a TOF pattern including four stimulation pulses 0.5 seconds apart from each other; and (c) a tetanus stimuli whereby the nerve is stimulated at a first frequency for a first amount of time and, after a pause lasting a predetermined duration of time, the nerve is stimulated at a second different frequency higher than the first frequency. Additionally, the timing of the predetermined stimulation pattern may occur during any of (a) pre-surgery to prevent esophageal intubation until the NMBA’s take effect; (b) during surgery to ensure that that NMBA’s are sufficiently sedating the user; and (c) post surgery to prevent premature removal of the mechanical respiratory mechanism. The temperature sensor 108 may be controlled by the monitoring device to sense the temperature at a predetermined time period. The predetermined time period during which the temperature sensor 108 may sense the skin temperature of the user any of (a) prior to stimulation of the nerve by the electrodes 110; (b) after stimulation of the nerve by electrodes 110; (c) simultaneously with the stimulation of the nerve by electrodes 110; and (d) any other predetermined time frame during which the user is being monitored by the monitoring device.

Figure 2 depicts the user's hand in a supine position having the adapter 100 positioned thereon. The adapter 100 shown herein includes similar structure and features to those shown and described above in Figure 1. Figure 2 shows the adapter 100 that includes the first section 104 formed from the soft flexible material positioned over the thumb 4 and having the first accelerometer 106 positioned at substantially a tip of the thumb 4. The first wire 107 couples the first accelerometer 106 to the monitoring device via cable 111 (shown in Figure 1). The second section 102 extends from an edge of the first section 104 and covers the heel 6 on the palm 7 of the hand 2. The second section 102, as discussed above
is formed from a semi-rigid material that functions as a support section to maintain the thumb 4 in a pre-loaded first position. The second section 102 also includes the temperature sensor 108 positioned over the heel 4 of the thumb 2. The second wire 109 couples the temperature sensor 108 to the monitoring device via the cable 111.

The supine view of the palm 7 side of the hand shown herein provides a view of the position of the second section 102 with respect to the first section 104. This view shows how the second section 102 pre-loads the thumb 4 in the first pre-loaded position. Specifically, Figure 2 depicts the embodiment, wherein the point at which the second section 102 meets the first section 104 is substantially between the metacarpophalangeal joint and the interphalangeal joint of the thumb. This is shown in the dashed circle labeled 200 in Figure 2. In this manner, the semi-rigid material of the second section 102 is able to provide sufficient force to pre-load the thumb into the predetermined first position.

Figure 3 depicts a side perspective view of the user having the adapter 100 positioned on a hand 2 thereof. The adapter 100 includes similar elements to those labeled and discussed above with respect to Figures 1 and 2. Figure 3 shows the thumb 4 of the hand 2 maintained in the first pre-loaded position. In response to stimulating the peripheral (ulnar) nerve via the electrodes 110 (shown in Figure 1) in the predetermined pattern, the thumb 4 is caused to twitch and move in a direction indicated by the arrow labeled 112. The flexible material 4 that forms the first section 104 positioned over the thumb 4 enables free movement of the thumb 4 and the accelerometer 106 automatically converts the physical motion of the thumb 4 into an electrical signal including data representing the physical motion of the thumb as it moves in direction 112. The movement of the thumb 4 in direction 112 exerts a force on the second section 102 of the adapter 100 and enables the thumb 4 to move out of the first pre-loaded position. The force associated with the twitch response is able to overcome the force exerted by the second section 102 on the thumb 4 which maintains the thumb in the first pre-loaded position when no stimulation is provided to the peripheral nerve (e.g. at rest). Because the thumb 4 is maintained in the first preloaded position when at rest, the amplitude of the acceleration measurement is higher and enables a more precise measurement of the NMT value when the thumb 4 moves in direction 112.
Figure 4 is an alternate embodiment of the adapter shown and described in Figures 1 - 3. As shown herein adapter 100a includes a first section 104 that not only covers the thumb 4 but also covers the heel 6 and corresponding top portion of the hand. The second section 102a functions as the support section and is positioned on a top side of the hand. The second section 102a may be substantially U-shaped and positioned over the metacarpophalangeal joint. In one embodiment, a first edge of the second section 102a is positioned at a point substantially between the metacarpophalangeal joint and the interphalangeal joint of the thumb and extends over the metacarpophalangeal joint of the thumb. A second end of the second section 102a ends at substantially a midpoint of the metacarpal bone of the thumb 4. The second section 102a may be concave such that the second section 102a does not rest directly on the skin of the user resulting in a space between the second section 102a and the hand of the user. This advantageously enables the second section 102a to provide support for the thumb 4 and maintains the thumb 4 in the first pre-loaded position. The second section 102a exerts a force on the thumb 4 to maintain the thumb 4 in the first pre-loaded position. However, in response to nerve stimulation, the twitch movement of the thumb 4 overcomes the force exerted by second section 102a and allows the thumb 4 to move in the direction represented by the arrow labeled 112 in Figures 1 and 3.

Figures 5 - 7 depict an alternate embodiment of an adapter 500 that is able to measure the neuromuscular transmission of a patient to which NMBA’s have been administered. Figure 5 shows an adapter 500 including a first section 504 that selectively receives a thumb 4 of a user therein. The first section 504 includes a first accelerometer 506 positioned at substantially a tip end of the thumb on the palm side thereof. The first section 504 may be formed from a thin, lightweight, flexible material that is breathable to allow the skin of the thumb 4 covered by the first section 504 to breathe. The first section 504 further includes a temperature sensor 508. The temperature sensor 508 is positioned substantially over the metacarpophalangeal joint of the thumb 4 on a palm side 7 of the hand 2. Both the accelerometer 506 and temperature sensor 508 operate in similar manner as described above in Figures 1 - 3.

The adapter 500 further includes a second section 102 and a third section 503. The second section 502 and third section 503 collectively function as a support section supporting the thumb 4 in a first pre-determined pre-loaded
position. The second section 502 includes a first curvilinear member 512 that extends from an edge of the first section 504 positioned substantially at a base of the thumb 4 and over the metacarpophalangeal joint thereof. In one embodiment, the first curvilinear member 512 originates at an edge of the first section 504 substantially adjacent to the temperature sensor 508 and extends over a surface of the palm 7 that covers the metacarpal bones of the pointer and middle fingers. The second section 502 further includes a second member 514 that is connected to an end of the curvilinear member 512 opposite the connection to the first section 504. The second member 514 may be positioned substantially over the metacarpal bones of the ring finger 8 and little finger 10 of the hand and extend in a direction parallel thereto.

The adapter 500 includes the third section 503. The third section 503 includes a first finger support 519 that is positioned on the ring finger 8 of the user. The first finger support 519 is connected to the second member 514 of the second section 502 via a first finger connector 518. The third section 503 further includes a second finger support 521 that is positioned on the little finger 10 of the user. The second finger support 521 is connected to the second member 514 of the second section 502 via a second finger connector 520. In one embodiment, each of the first finger support 519 and second finger support 521 are rings that are selectively positioned at a base of the ring finger 8 and little finger 10, respectively. Additionally, in this embodiment, the first and second finger connectors 518 and 520 extend substantially parallel to one another.

The second section 502 of the adapter 500 is selectively adjustable to be adaptable for users having different palm sizes. The second member 514 includes a plurality of recesses 516 extending therethrough and the curvilinear member 512 includes a plurality of tabs 513 extending upwards from a surface thereof. When fitting the adapter 500 to a hand 2 of the user, the first section 504 is positioned over the thumb 4 and the third section 503 is positioned at the base of the ring and little finger 8 and 10, respectively, the size of the second section 502 may be selectively adjusted by positioning a respective one of the plurality of tabs 513 within a respective one of the plurality of recesses 516. By securing a tab 513 in a recess 516, the second and third sections 502 and 503, respectively function to support the first section 504 in the first predetermined pre-loaded position.
In the embodiment shown in Figure 5, the third section 503 serves to anchor the second section 502 in place thereby providing support to the first section 504 that covers the thumb 4. The support provided by the second and third sections 502, 503 advantageously results in a force being applied to the first section 504 and maintains the thumb 4 in the first predetermined pre-loaded position. The second and third sections 502, 503 further advantageously serve to guide any motion of the thumb 4 in the event that the force exerted by the second and third sections is overcome (e.g. in response to neural stimulation of the peripheral nerve).

A cable 511 connects the adapter 500 to a monitoring device (see Fig. 10, either Ref. Nos 1008 or 1018). The cable 511 includes at least two electrodes 510 positioned substantially over the peripheral (e.g. ulnar) nerve. The cable 511 also includes a first connection wire 507 that couples the first accelerometer 506 to the monitoring device and enables acceleration data sensed by the first accelerometer 506 to be transmitted to the monitoring device for use in determining a neuromuscular transmission measurement value. The cable 511 also includes a second connection wire 509 that couples the temperature sensor 508 to the monitoring device. The second connection wire 509 enables temperature data representing a skin temperature of a user to be transmitted to the monitoring device for use in determining if the value sensed by the accelerometer is valid by detecting whether the flow of blood through the thumb is of a sufficient rate. The wires 507, 509 may meet at a junction point. At the junction point, the wires 507, 509 may run substantially adjacent one another along a length of the cable 511 to connect to an input of the monitoring device. The patient monitoring device is able to receive and process any data (e.g. acceleration data and/or temperature data) being transmitted via wires 507, 509 to determine the effectiveness of anesthesia on the patient by calculating a value corresponding to the neuromuscular transmission of the user.

In operation, the monitoring device causes the electrodes 510 to stimulate the peripheral nerve over which they are positioned. Stimulation of the peripheral nerve causes a reflex response in the user whereby at least the thumb 4 is caused to move in a direction indicated by the arrow labeled with reference numeral 522. The direction of movement 522 is toward the palm 7 and in a trajectory towards the ring finger 8 and little finger 10 of the hand 2. The reflex response resulting
from the twitch overcomes the force exerted on the thumb 4 by the second section 502. The curvilinear member 512 and the second member 514 of the second section is compressed enabling movement of the thumb 4 in direction 522. In response to the thumb 4 moving in direction 522, the first accelerometer 506 automatically senses the acceleration of the thumb 4 and converts the physical motion of the thumb movement into an electrical data signals. The data signal representing the thumb movement sensed by the accelerometer 506 is communicated via first wire 507 through cable 511 and is received by the monitoring device. Additionally, the temperature sensor 508 may sense a skin temperature of the user. Data representing the sensed skin temperature which represents an amount of blood flow to and from the thumb 4 is transmitted via second wire 509 through cable 511 for receipt by the monitoring device. As will be discussed hereinafter with respect to Figures 10 and 11, the monitoring device uses the acceleration data and the temperature data as inputs for an algorithm that determines a value corresponding to the neuromuscular transmission for the user.

Figure 6 is a view of the hand 2 of the user in a supine position having the adapter 500 positioned thereon. As shown herein, the thumb 4 is in the first pre-loaded position and the second and third sections 502 and 503, respectively, maintain an angle between the thumb 4 and the pointer finger at a predetermined angle thereby providing a consistent initial starting point from which movement of the thumb 4 in response to neural stimulation can be measured.

Figure 7 is side perspective view of the hand 2 of the user having the adapter 500 positioned thereon. As shown herein, the thumb 4 may be caused to move in direction 522 in response to neural stimulation by the electrodes 510 (Fig. 5). By moving in direction 522, the thumb 4 exerts a force sufficient to overcome the force exerted by the second section 502. The movement of the thumb 4 causes the curvilinear section 512 and second member 514 to be compressed enabling the accelerometer 506 to measure the physical motion of the thumb 4. However, the second section 502 further serves to guide any movement of the thumb 4 in the natural opposable motion towards the ring finger 8 and little finger 10.

Figures 8 and 9 depict an alternate embodiment of an adapter 800 that is able to measure the neuromuscular transmission of a patient to which NMBA's have been administered. Figure 8 shows an adapter 800 including a first section 804 that selectively receives a thumb 4 of a user therein. The first section 804
includes a first accelerometer 806 positioned at substantially a tip end of the
thumb 4 on the palm side 7 thereof. The first section 804 may be formed from a
thin, lightweight, flexible material that is breathable to allow the skin of the thumb
4 covered by the first section 804 to breathe. The first section 804 further includes
a temperature sensor 808. The temperature sensor 808 is positioned substantially
over the metacarpophalangeal joint of the thumb 4 on a palm side 7 of the hand 2.
Both the accelerometer 806 and temperature sensor 808 operate in similar manner
as described above in Figures 1 - 3.

The adapter 800 further includes a second section 802 and a third section
803. The second section 802 and third section 803 collectively function as a
support section supporting the thumb 4 in a first pre-determined pre-loaded
position. The second section 802 is formed from a curvilinear member that
extends from an edge of the first section 104 that is positioned substantially at a
base of the thumb 4 positioned over the metacarpophalangeal joint thereof. In one
embodiment, the curvilinear member of the second section 802 originates at an
deck of the first section 804 substantially adjacent to the temperature sensor 808
and extends over a surface of the palm 7 that covers the metacarpal bones of at
least the pointer, middle and ring fingers. In one embodiment, the curvilinear
member of the second section 802 may be formed from plastic or metal.
Additionally, the curvilinear member may be formed as any of (a) a substantially
flat member; (b) a solid tubular member; and (c) a hollow tubular member.

The adapter 800 includes the third section 803. The third section 803
includes a first finger support 812 positioned on the ring finger 8 of the user and a
second finger support 814 positioned on the little finger 10 of the user. A bridge
member 810 connects the first finger support 812 and the second finger support
814 together. The third section 803 further includes a second accelerometer 816.
The second accelerometer 816 is shown positioned on the second finger support
814 on the little finger 10 of the user's hand. This positioning is shown for
purposes of example only and the second accelerometer may also be positioned on
the first finger support 812. Alternatively, a third accelerometer (not shown) may
be positioned on the finger support that does not include the second accelerometer
516. In one embodiment, each of the first finger support 812 and second finger
support 814 are rings that are selectively positioned over the middle phalanges of
the ring finger 8 and little finger 10, respectively and the second accelerometer
516 is positioned substantially adjacent to a tip of the little finger 10. The positioning of the third section 803 and the second accelerometer 816 being substantially at a tip section of the ring and middle finger advantageously ensure that the measurement amplitude is sufficiently high to derive a precise measurement correlating the twitch response in the ring finger and little finger. In one embodiment, the second section 802 and third section 803 may be selectively adjustable thereby enabling the adapter in Figure 8 to be selectively fit to users having different palm sizes. For example, the third section may include a channel positioned on a face of the bridge member 810 through which an end of the second curvilinear second member 802 may be received. The curvilinear second member 802 may slide through the channel and, upon fitting the adapter to a user’s hand, a securing mechanism may be used to secure the second member 802 within the channel thereby prevent further adjustment and maintaining the adapter in a desired position such that the thumb and ring/litter fingers are biased in their first pre-loaded positions.

In this embodiment, the inclusion of a second accelerometer 816 advantageously provides an additional data value from which the NMT value may be calculated. The inclusion of motion data from a second accelerometer 816 is advantageous because stimulation of the peripheral nerve may result not only in movement of the thumb in a direction indicated by the arrow labeled with reference numeral 822 but also in movement of at least one of the ring finger 8 and little finger 10 in a direction towards the thumb 4 as indicated by the arrow labeled with reference numeral 824. Additionally, at time, neural stimulation may not result in movement of the thumb 4 in direction 822 but instead may only cause the ring and/or little finger 8, 10 to move in direction 824. In these instances when stimulation does not result in movement of the thumb, a healthcare professional charged with monitoring an NMT value may make an incorrect conclusion about the effectiveness of the NMBA. By automatically monitoring both the movement of the thumb 4, the ring finger 8 and the little finger 10 the healthcare professional is provided with an additional source of data from which a conclusion about the effectiveness of any NMBA’s may be made.

In the embodiment shown in Figure 8, the third section 803 serves to anchor the second section 802 in place thereby providing additional support to the first section 804 that covers the thumb 4. The support provided by the second and
third sections 802, 803 advantageously results in a force being applied to the first section 804 and maintains the thumb 4 in the first predetermined pre-loaded position. The second and third sections 802, 803 further advantageously serve to guide any motion of the thumb 4 in the event that the force exerted by the second and third sections is overcome (e.g. in response to neural stimulation of the peripheral nerve).

While not shown herein, one skilled in the art will understand that the adapter 800 includes a cable similar to cables 111 and 511 in Figures 1 and 5, respectively, that connects various components of the adapter 800 to a monitoring device (see 1008 or 1018 in Fig. 10) as well as the electrodes that stimulate the peripheral nerve. A first connection wire 807 couples the first accelerometer 806 to the monitoring device and enables acceleration data sensed by the first accelerometer 806 to be transmitted to the monitoring device for use in determining a neuromuscular transmission measurement value. A second connection wire 809 couples the temperature sensor 808 to the monitoring device. The second connection wire 809 enables temperature data representing a skin temperature of a user to be transmitted to the monitoring device for use in determining if the value sensed by the accelerometer is valid by determining whether there is sufficient blood flow through the thumb 4. A third connection wire 817 couples the second accelerometer 817 to the monitoring device and enables acceleration data associated with at least one of the ring and little finger sensed by the second accelerometer 816 to be transmitted to the monitoring device for use in determining the neuromuscular transmission measurement value. The wires 807, 809 and 817 may meet at a junction point and may continue to run substantially adjacent one another along a length of the cable to connect to an input of the monitoring device. The monitoring device is able to receive and process any data (e.g. acceleration data and/or temperature data) being transmitted via wires 807, 809 and 817 to determine the effectiveness of anesthesia on the patient by determining a value corresponding to the neuromuscular transmission in the user.

In operation, the monitoring device causes electrodes positioned adjacent the peripheral nerve to stimulate the peripheral nerve. This stimulation causes a reflex response in the user whereby at least one of the thumb 4 is caused to move in a direction indicated by the arrow labeled with reference numeral 822 and the
ring finger 8 and little finger 10 are caused to move in the direction indicated by reference numeral 824. The direction of movement 822 of the thumb 4 is toward the palm 7 and in a trajectory towards the ring finger 8 and little finger 10 of the hand 2 and the direction of movement 824 of the ring and/or little finger 8, 10 is towards the palm 7 and in a trajectory towards the thumb 4. This movement reflects the natural opposable movement of the thumb and ring/little fingers. The reflex response resulting from the stimulation overcomes the force exerted on the thumb 4 by the second section 802. The force exerted by the thumb 4 and/or ring and little fingers 8,10 causes the curvilinear member of the second section 802 to be compressed enabling movement of the thumb in direction 822 and movement of the ring and little finger 8, 10 in direction 824. In response to the thumb 4 moving in direction 822, the first accelerometer 806 automatically senses the acceleration of the thumb 4 and converts the physical motion of the thumb movement into a first electrical data signal representing the sensed movement of the thumb 4. The data signal representing the thumb movement sensed by the accelerometer 806 is communicated via first wire 807 through the cable and is received by the monitoring device. In response to the ring and little finger 8, 10 moving in direction 824, the second accelerometer 816 automatically senses the acceleration of the ring and little finger 8, 10 and converts the physical motion thereof a second electrical data signal representing the sensed movement of the ring and little finger 8, 10. The second data signal representing the ring and little finger movement sensed by the second accelerometer 816 is communicated via the third wire 817 through the cable and is received by the monitoring device. Additionally, the temperature sensor 808 may sense a skin temperature of the user. Data representing the sensed skin temperature which represents an amount of blood flow to and from the thumb 4 is transmitted via second wire 809 through the cable for receipt by the monitoring device. As will be discussed hereinafter with respect to Figures 10 and 11, the monitoring device uses the acceleration data and the temperature data as inputs for an algorithm that determines a value corresponding to the neuromuscular transmission for the user.

Figure 9 is side perspective view of the hand 2 of the user having the adapter 800 positioned thereon. As shown herein, the thumb 4 may be caused to move in direction 822 in response to neural stimulation by the electrodes 510 (Fig. 5). Additionally, neural stimulation of the peripheral nerve may cause the ring
finger 8 and/or the little finger 10 to move in the direction indicated by the arrow labeled 824. By moving in directions 822 and 824, the thumb 4 and ring finger/little finger 8, 10 exert a force sufficient to overcome the force exerted by the second section 802 causing the curvilinear section of the second section 802 to be compressed. The first accelerometer 806 measures the physical motion of the thumb 4 and the second accelerometer 816 measures the physical motion of the ring finger and/or little finger 8, 10, respectively. This advantageously provides two different data values for use in measuring the NMT value identifying the effect of the NMBA on the user. By using two different data values either collectively or individually, the NMT value generated reflects a more precise indication of the effect of the NMBA's on the user.

Figure 10 is an exemplary block diagram of the NMT measurement system according to invention principles. The system includes an adapter 1000 selectively positionable on a hand of a patient 1001. The adapter 1000 may be any of adapters 100, 500 and 800 described above with respect to Figures 1 - 9. The adapter 1000 is able to selectively measure the physical motion of the thumb and ring/little fingers of a user in response to neural stimulation. As shown herein the adapter includes the first accelerometer 1002, the second accelerometer 1004 and a thermistor 1006 which operate in a manner similar to the corresponding components described above with respect to Figures 1 - 9.

The first accelerometer 1002 is coupled via first wire 1003 to an input of a neurotransmission measurement (NMT) apparatus 1008 that selectively determines an NMT value for the patient that quantifies the effectiveness of NMBA’s on the patient. Data representing the physical motion of the thumb sensed by the first accelerometer is communicated via the first wire 1003 and received at the input of the NMT measurement apparatus 1008. The thermistor 1006 is coupled via a second wire 1007 to an input of the NMT apparatus 1008. Data representing a temperature of the skin is communicated via the second wire 1007 and received at the input of the NMT measurement apparatus 1008. The second accelerometer 1004 is coupled via third wire 1005 to an input of a neurotransmission measurement (NMT) apparatus 1008 that selectively determines an NMT value for the patient that quantifies the effectiveness of NMBA’s on the patient. Data representing the physical motion of the ring and little finger sensed by the second accelerometer 1004 is communicated via the
third wire 1005 and received at the input of the NMT measurement apparatus 1008. The first, second and third wires 1003, 1007 and 1005 may travel along cable 1009 which selectively couples the respective wires to an input on the NMT measurement apparatus. Data sensed by the first accelerometer 1002, the second accelerometer 1004 and thermistor 1006 is used to selectively calculate and/or otherwise determine a value corresponding to the neuromuscular transmission for a particular patient at a given time as described below.

The cable 1009 may also connect at least one electrode 1011 with the NMT measurement apparatus 1008. When the adapter 1000 is positioned on the hand of the user in the manner described above in Figures 1 - 9, the at least one electrode 1011 will be positioned substantially over the peripheral nerve of the user. The at least one electrode 1011 applies an electrical stimuli to the peripheral nerve at predetermined intervals in predetermined patterns as discussed below.

The NMT measurement apparatus 1008 is provided for determining a value corresponding to the neurotransmission measurement for a user. The NMT measurement apparatus includes a control processor 1010 that executes instructions controlling the operation of the NMT measurement apparatus. The control processor 1010 is electrically coupled to a nerve stimulator 1012 and a measurement processor 1014. The control processor 1010 executes a stimulation module at predetermined intervals that selectively controls the nerve stimulator 1012. The nerve stimulator 1012, in response to a control signal, generates a signal that is transmitted via cable 1009 to cause the at least one electrode 1011 to apply an electrical impulse. The control processor 1010 may control the nerve stimulator 1012 to apply a supramaximal electrical stimuli having a current ranging substantially between 10mA to 60mA. Additionally, the control processor 1010 may selectively stimulate the nerve in any one of a predetermined set of neural stimulation patterns. The neural stimulation pattern implemented includes selectively choosing a current value for the stimulus and a pattern of application of the chosen current value. The neural stimulation pattern implemented at a given time depends on the type of NMT measurement needed. The control processor 1010 may operate to stimulate the nerve using any of one the following neural stimulation patterns. For example, the control processor 1010 may implement a single twitch stimulation pattern that includes providing a single stimulus to derive an NMT value for comparison with a threshold. In the single twitch mode a
single supramaximal electrical stimulus is applied to a peripheral nerve at frequency from 1.0 Hz (once every second) to 0.1 Hz (once every 10 seconds). The control processor may also implement a train of four (TOF) neural stimulation pattern. In the train of four neural stimulation pattern, the neural stimulator 1012 applies a series of four stimuli to the peripheral nerve to determine a TOF ratio corresponding to a level of muscle paralysis in the user. In the TOF pattern, four supramaximal electrical impulses are administered every 0.5 seconds (2 Hz) When used continuously, each set of four (e.g. train) of stimuli normally is repeated every 10th to 20th second. The number of resulting muscle twitches corresponds to the amount of muscle paralysis whereby an ideal level of paralysis is represented by two twitches being detected. A third type of neural stimulation pattern implemented by the control processor 1010 is the post-tetanic (PTC) pattern. The post-tetanic pattern is used to measure response during deep relaxation, when responses are no longer present from train-of-four stimulation. In the post-tetanic pattern, a tetanic stimulus is applied. The tetanic stimulus may be a 50 Hz signal for 5 seconds followed by a pause of 5 seconds, then single stimulations until no more responses are observed. In PTC mode, single twitches of 200 ms pulse width (by default) are applied for one second, and the twitches are counted to determine a residual amount of NMBA in the patient.

The electrical impulse applied by the at least one electrode 1011 in response to the signal received from the nerve stimulator 1012 causes the peripheral nerve to be stimulated in any of the above discussed neural stimulation patterns resulting in a twitch (reflex) response in at least one of the thumb and ring/little finger of the hand. The twitch response causes the thumb and/or ring/little finger to exert a force on the adapter 1000 great enough to overcome the force initially exerted on the hand by the adapter 1000 and thereby move the thumb and/or little and ring fingers from their first pre-loaded position. Movement from the first preloaded position results in the first and second accelerometers 1002 and 1004, respectively, measuring the physical motion of the twitch response to quantify an effect of the NMBA's on the user. Data representing the physical motion of the thumb and ring finger is communicated via the cable 1009 and received at the input of the NMT apparatus.

The measurement processor 1014 is coupled between the input of the NMT apparatus and the control processor 1010 and receives data from the first
and second accelerometer 1002 and 1004 as well as the thermistor 1006. The control processor 1010 automatically executes an NMT measurement algorithm that uses the data sensed from the first and second accelerometers 1002 and 1004, respectively to determine an NMT measurement value for the patient. Additionally, the control processor 1010 may control the thermistor 1006 to measure a skin temperature on the hand of the user at predetermined intervals to determine if there is sufficient circulation in the thumb of the patient at a given time. In exemplary operation, the NMT measurement algorithm executed by the measurement processor 1014 determines if the data received by the measurement processor 1012 is derived from the first accelerometer 1002, the second accelerometer 1004 or both the first and second accelerometers 1002 and 1004. The measurement processor 1012 further receives and uses data sensed from the thermistor 1006 that represents the temperature of the skin at any given time. The measurement processor 1014 uses these data values in a number of ways to determine an NMT value associated with a patient to identify and determine the effectiveness of the NMBA's on the patient.

In one embodiment, in response to electrical stimuli applied to the peripheral nerve via the at least one electrode 1011 at the direction of the nerve stimulator 1012, the measurement processor 1014 selectively receives data representing the twitch reflex response (e.g. physical motion) of the thumb from the first accelerometer 1002. The thumb reflex response data is communicated via the first communication wire 1003 over cable 1009 and received by the measurement processor 1014. Upon receipt thereof, the measurement processor 1014 automatically identifies the source of the received data as being from the first accelerometer 1002 and queries if additional data from the second accelerometer 1004 is present. If no additional data is sensed by the second accelerometer 1004, the measurement processor 1014 processes the thumb reflex response data by comparing the thumb reflex response data to a threshold value to determine an value corresponding to the neuromuscular transmission associated with the patient at a given time. The NMT value quantifies the depth of anesthesia for the patient and may correlate the effectiveness of the NMBA administered to the patient. The NMT value derived from thumb reflex data sensed from the first accelerometer 1002 is obtained in a known manner using conventional principles of accelomyography. In this embodiment, control processor 1010 may cause the
measurement processor 1014 to obtain skin temperature data sensed by the thermistor 1006. The measurement processor 1014 may compare the sensed skin temperature data to a known threshold range that indicates an acceptable level of blood flow circulating through the thumb. As the body and the skin temperature varies from patient to patient, in part dependent upon the body mass and medical condition of the patient, the control processor 1010 may supply a baseline acceptable temperature range which may be used by the measurement processor to compare with the measured skin temperature of the patient. In one embodiment, a clinician may enter an upper and lower temperature value for the acceptable temperature range for the particular patient. In another embodiment, the control processor 1010 may selectively acquire upper and lower temperature values from a source of temperature data based on the type of procedure being performed on the patient. The result of this comparison may be used to identify whether or not there is sufficient blood flow to the thumb to determine if the sensed acceleration values are valid. In another embodiment, the measured skin temperature may be used as a reference point for the clinician. If the measurement processor 1014 determines that the temperature data sensed by thermistor 1006 is within the acceptable range, the NMT measurement algorithm determines the NMT value as discussed above. If the measurement processor 1014 determines that the temperature data includes a temperature outside the threshold range, the measurement processor 1014 flags the thumb reflex data sensed by the first accelerometer 1002 as being potentially inaccurate. In response to identifying thumb reflex data as being potentially inaccurate, the measurement processor 1014 may automatically disregard the thumb reflex data and request that the control processor 1010 cause the nerve stimulator 1012 to re-stimulate the peripheral nerve to obtain a second set of data representing the thumb reflex response from the first accelerometer 1002. Alternatively or additionally, the measurement processor 1014 may generate an alert message and provide the alert message to the communication processor 1016 which may at least one of (a) cause a display unit 1020 to display an indicator corresponding to the information in the alert message (e.g. change a color of LED display light or provide a textual indication of the content of the alert message); (b) control an alarm unit to generate any of a visual, audio or tactile alert indicative of the information contained in the alert message; and (c) communicate the alert message via a
network 1024 for receipt by a remote computing system 1026 (e.g. a healthcare information system) in order to update patient record information or provide a healthcare professional at a remote location with information contained in the alert message.

In another embodiment, the measurement processor 1014 may also receive data representing the twitch reflex response of the ring and/or little finger in response to electrical stimuli being applied to the peripheral nerves by the at least one electrode 1011. This embodiment includes all features described in the immediately preceding embodiment whereby reflex response data for the thumb as well as skin temperature data is sensed by the first accelerometer 1002 and the thermistor 1006, respectively. However, in this embodiment, in response to the electrical stimulation of the peripheral nerve, the measurement processor 1014 determines that ring and little finger twitch response data is also being transmitted via the third wire 1005 and being received thereby. As discussed above, the measurement processor 1014 identifies the source of data from which the reflex response is derived. If the measurement processor 1014 determines that thumb reflex data sensed by the first accelerometer 1002 is present along with ring and little finger reflex response data sensed by the second accelerometer 1004 is present, the measurement processor 1014 executes a modified NMT measurement algorithm that takes into account both sets of data when determining the NMT value associated with the patient at the given time. For example, the NMT measurement algorithm may average the values of the thumb reflex data with the ring and little finger reflex data to generate a composite reflex response data value. The NMT measurement algorithm may use the composite reflex response data value in the known manner to generate the NMT value indicative of depth of anesthesia for the patient. In another example, the NMT measurement algorithm may compare the thumb reflex response value with a first threshold value of known reflex values that identify a depth of anesthesia. The NMT measurement algorithm implemented by the measurement processor 1014 may also compare the ring and little finger reflex response value with a second threshold of known reflex response values associated with the ring and little finger that may identify a depth of anesthesia. The measurement processor 1014 may then assign a weight value to each of the thumb reflex response data value and the ring and little finger reflex response data value for use in calculating a weighted average to generate
the composite reflex response value which may be used in the NMT measurement algorithm to generate the NMT value indicative of depth of anesthesia for the patient.

In a further embodiment, the measurement processor 1014 may determine that the data received is only data representing the reflex response of the ring and little finger. If the measurement processor 1014 determines that only ring and little finger response data is received, the measurement processor 1014 may use the received ring and little finger response values as inputs to the NMT measurement algorithm to generate the NMT value indicative of depth of anesthesia for the patient.

In any of the above embodiments describing the different data sources derived from either or both the first and second accelerometers 1002 and 1004, respectively, the measurement processor 1014 may request and utilize the temperature data sensed by the thermistor 1006 in the manner described above. The skin temperature data sensed by the thermistor 1006 advantageously enables the NMT measurement apparatus to perform a check to determine if one or more of the data values sensed by the accelerometers 1002, 1004 is valid and should be used by the NMT measurement algorithm to determine the NMT value associated with the patient.

As discussed above, the communication processor 1016 is coupled between the measurement processor 1014 and the control processor 1016. The communication processor 1016 facilitates bi-directional communication between the NMT measurement apparatus 1008 and other systems. For example, the communication processor 1016 automatically communicates the NMT value determined by the measurement processor 1014 to a monitoring device 1018 that is able to selectively monitor at least one other patient parameter (e.g. ECG monitor and/or ventilator). The NMT value determined by the NMT measurement apparatus 1008 may be selectively provided to the monitoring device 1018 to further update and provide a healthcare professional with a more complete set of patient information. Alternatively, the communication processor 1016 may communicate the NMT value determined by the measurement processor 1014 to a remote system 1026 via a network 1024. The communication of the NMT value may be performed at predetermined intervals or in response to receipt of a user request for an NMT value originating from the remote system 1026. In another
embodiment, the remote system 1026 may generate a request for an NMT value at a given time that is received by the communication processor 1016. The communication processor 1016 may cause the control processor 1016 to initiate the NMT measurement process immediately to obtain the most current NMT value for the patient.

The NMT measurement algorithm implemented by the NMT measurement apparatus may operate at predetermined time periods during the sedation of the patient. For example, the control processor 1010 may initiate a first NMT measurement algorithm that measures the NMT value prior to intubation of the patient to determine if the NMBA’s have had sufficient time to sedate the patient to allow for intubation thereof. The control processor 1010 may initiate a second measurement algorithm that continually measures the NMT value during a predetermined interval corresponding to a length of a procedure. In one embodiment, the second NMT measurement algorithm may be automatically initiated in response to receiving a signal indicating that respiration for the patient is being performed mechanically. The control processor 1010 may execute a third NMT measurement algorithm that obtains the NMT value at predetermined time periods after the procedure has been completed to determine when a patient's natural respiratory function has returned thereby indicating that the breathing tube may be removed. Furthermore, for any of the first, second or third NMT measurement algorithms, the control processor 1010 may cause the nerve stimulator 1012 to generate an electrical impulse at predetermined intervals whereby each impulse is generated in a predetermined pattern and lasts for a predetermined duration.

By providing a distinct NMT measurement apparatus 1008 that connects to an input of a patient monitoring device 1018, as shown herein, the system is modular and may be used during any type of surgical procedure that requires the administration of NMBA’s to a patient. This is advantageous because different procedures may require the use of different patient monitoring devices 1018 capable of determining and monitoring different types of patient parameters. Thus, the NMT measurement apparatus 1008 and corresponding adapter 1000 may be selectively connected to any type of patient monitoring device 1018 thereby enabling monitoring of the desired patient parameter as well being able to
continually determine an NMT value correlating to a depth of anesthesia for the patient.

In another embodiment, the components and associated circuitry that forms the NMT measurement apparatus 1008 may be formed integrally with a patient monitoring device 1018 such that the cable 1009 directly connects the adapter 1000 to the patient monitoring device 1018. In this embodiment, the patient monitoring device 1018 would directly calculate the NMT value for the patient at a given time in the manner described above.

Figure 11 is a flow diagram detailing an exemplary algorithm executed by the control processor (1016 in Fig. 10) of the NMT apparatus for use in determining an NMT value for a particular patient at a given time. At step 1100, an adapter (1000 in Fig. 10) is positioned on a hand of a user and maintains the least one of (a) a thumb; (b) ring finger and (c) a little finger in a first pre-loaded position. The adapter advantageously maintains the thumb and ring/little fingers in a predetermined position relative to one another and the other fingers on the hand as discussed above in Figures 1 - 9. The adapter may be any of the adapter embodiments described in Figures 1 - 9 that include at least one of (a) first accelerometer positioned at substantially a tip of the thumb; (b) a second accelerometer positioned at substantially a tip of the ring or little finger; and (c) a temperature sensor positioned at substantially at one of a base of a thumb of a heel of the thumb.

At step 1102, the control processor at least one of determines and identifies a stage of a procedure being performed on a patient and selecting an NMT calculation algorithm associated with the identified stage. This may include, for example, determining if the patient is in one of (a) a pre-surgical stage; (b) undergoing active surgery; or (c) post-surgical stage. Identifying the stage of the procedure is important because each respective stage may have different ranges of acceptable threshold values for the NMT value which ultimately determine the effectiveness of the NMBA on the patient at the given time.

At step 1104, the control processor controls the nerve stimulator (1012 in Fig. 10) to generate a signal causing the at least one electrodes (1011 in Fig. 10) to apply a stimulus to the peripheral nerve on which they are positioned resulting in the movement of at least one of (a) thumb; (b) ring finger and (c) little finger in their natural opposable trajectory from an initial pre-loaded position first
positioned. The resulting movement (e.g. reflex response) causes the thumb and/or
ring and little finger to exert a force on the adapter sufficient to overcome the
force exerted by the adapter on the thumb and ring/little finger. The signal
generated by the nerve stimulator may result in the at least one electrode applying
any of (a) a single stimulus to the peripheral nerve or (b) a predetermined pattern
of impulses to the peripheral nerve. The signal may also include duration
information that selectively controls a duration of the single of multiple impulses
applied to the nerve by the at least one electrode.

At step 1106, in response to the movement of the at least one (a) thumb;
(b) ring finger; and (c) little finger; the respective accelerometers sense the
physical motion associated with the movement and convert the physical motion to
electrical signals. Additionally at step 1107, the temperature sensor may sense a
temperature of the skin for use in determining whether the blood flow to the
thumb is sufficient. The electrical signals including data representing motion of
the thumb and/or motion of the little/ring finger generated by any of the first and
second accelerometers, respectively and the data representing the skin temperature
are transmitted to and received by a measurement processor (1014 in Fig. 10) of
the NMT measurement in step 1108.

In step 1110, the measurement processor (1014 in Fig. 10) determines the
type and source of the data received and an NMT value for the patient is
calculated based on the type and source of the data received in step 1112 using
data representing the physical motion of the thumb and/or ring/little finger. In one
embodiment, step 1110 may determine that the data received is sensed by the first
accelerometer on the thumb and the NMT value is calculated based on thumb
acceleration data. In another embodiment, step 1110 may determine that the data
received is sensed by both the first and second accelerometers and may perform a
statistical calculation using the data from the first and second accelerometer to
derive a composite acceleration data that is used to calculate the NMT value. IN a
further embodiment, step 1110 may determine that the data received is sensed by
the second accelerometer on the ring/little finger and the NMT value is calculated
based on ring/little finger acceleration data. In step 1114, the measurement
processor automatically determines the validity of the NMT value calculated in
step 1112 by comparing the temperature data with a threshold range of acceptable
temperature values that indicate sufficient blood is flowing through the thumb. If
the temperature value is outside the acceptable range, the resulting NMT may be deemed invalid due to insufficient blood flow to the thumb. If the determination in step 1114 indicates a valid NMT value, the control processor may cause the NMT value to be provided to a healthcare professional for review and analysis thereof in step 1116. If the determination in step 1114 is negative, the method may recalculate the NMT value in step 1115 by repeating steps 1102 - 1114. If the recalculated NMT value determined in step 1115 still remains outside the acceptable threshold range, the control processor provides a notification of a potential problem to a healthcare professional in step 1117. The notification provided in step 1117 may include at least one of (a) displaying an indicator on a display screen that notifies the healthcare professional of a potential problem; (b) signaling an alarm unit to notify the healthcare professional of the potential problem; (c) communicating a message to a remote system via a network to notify a remotely located healthcare professional of a potential problem.

The resulting NMT value provided in step 1116 may be used by a healthcare professional to determine the effectiveness of the NMBA's being administered to the patient during the particular stage of the procedure. Thus, the NMT value advantageously quantifies the depth of anesthesia and provides a metric to the healthcare professional for use in determine whether or not the course of NMBA's being administered to the patient should be one of (a) maintained at a current level; (b) increased to a higher level; and (c) reduced to a lower level.

The steps described with respect to Figure 11 may be repeated to continually calculate and monitor the NMT value associated with the patient throughout the procedure. The repetition may be continual or initiated at predetermined intervals during the current stage of the procedure. In the event that the stage of the procedure changes, the steps described in Figure 11 may be used with the difference being the threshold values used for determining the NMT value and the validity thereof.

Figure 12 provides a method of using the adapters described above with respects to Figures 1 - 9. The method of Figure 12 represents a method of determining a neuromuscular transmission value for a patient under an effect of a neuromuscular blocking agent. In step 1200, an accelerometer is retained at tip of a thumb of the patient. In step 1202 the thumb of the patient is supported using a
support member to maintain the thumb in a predetermined position and restricts movement of the thumb from the predetermined position. A stimulus is applied to a nerve of a patient causing the thumb to exert a force on the support member and move from the predetermined position in step 1204. In step 1206, the accelerometer measures the movement of the thumb from the predetermined position and a neuromuscular transmission value is determined for the patient using the measured movement of the thumb in step 1208. The neuromuscular transmission value determined in step 1208 is indicative of an effectiveness of the neuromuscular blocking agents.

In one embodiment, step 1200 may also include retaining a second accelerometer at substantially a tip end of at least one of the ring finger and little finger of the patient and step 1206 may further include measuring the movement of at least one of the ring finger and little finger using the second accelerometer in response to said activity of applying a stimulus to the nerve. In this embodiment, step 1208 may also include determining the neuromuscular transmission value for the patient using at least one of the measured movement of the thumb and measured movement of the at least one of the ring finger and little finger.

In another embodiment, the method may include retaining a temperature sensor at a substantially fixed position on a palm of the hand of the patient and sensing a skin temperature using the temperature sensor. The sensed skin temperature may be used to determine whether the determined neuromuscular transmission value is valid.

The apparatus and system described hereinabove with respects to Figures 1 - 12 advantageously enables a healthcare professional to obtain a precise level of neuromuscular transmission in a patient under the influence of a neuromuscular blocking agent. The apparatus advantageously supports the thumb in a predetermined position enabling a consistent starting point for measuring thumb movement in response to nerve stimulation. The consistent starting point advantageously results in a higher amplitude measurement that is more precise metric for determining the NMT value. The apparatus further provides a second accelerometer positioned on the little and/or ring finger to obtain a second data value for use in calculating the NMT value. The second data value further enhances the ability of a healthcare professional to assess the effectiveness of the NMBA’s at a given time because nerve stimulation not only results in twitching of
the thumb but may also result in twitching of the ring and little fingers.

Although the invention has been described in terms of exemplary embodiments, it is not limited thereto. Rather, the appended claims should be construed broadly to include other variants and embodiments of the invention which may be made by those skilled in the art without departing from the scope and range of equivalents of the invention. This disclosure is intended to cover any adaptations or variations of the embodiments discussed herein.
What is claimed is:

1. An apparatus for use in determining a neuromuscular transmission value for a patient, the apparatus comprising:
   a cuff for receiving a thumb of a patient therein;
   an accelerometer positioned on the cuff at substantially a tip of the thumb;
   a support member coupled to the cuff that maintains the thumb in a predetermined position and restricts movement of the thumb; and
   a stimulation mechanism that applies a stimulus causing the thumb to move and exert a force on the support member sufficient to overcome the restricted movement, wherein the accelerometer generates an electrical signal indicative of movement of the thumb for use in determining a neuromuscular transmission value.

2. The apparatus as recited in claim 1, further comprising
   a temperature sensor maintained in a fixed position on a palm side of a hand of the patient for selectively sensing a skin temperature for measuring a rate of blood flow to the thumb.

3. The apparatus as recited in claim 2, wherein
   the sensed skin temperature is used in determining if the neuromuscular transmission value is valid based on the measured rate of blood flow.

4. The apparatus as recited in claim 2, wherein
   the temperature sensor is positioned on the cuff at a position opposite the accelerometer at a base of the thumb.

5. The apparatus as recited in claim 2, wherein
   the temperature sensor is positioned on the support member on a heel of the thumb.
6. The apparatus as recited in claim 1, wherein
the support member maintains a predetermined angle between the
thumb and a pointer finger.

7. The apparatus as recited in claim 1, wherein
the cuff is formed from flexible material and the support member is
formed from semi-rigid material, the semi-rigid material exerting a force on the
thumb sufficient to maintain the thumb in the predetermined position.

8. The apparatus as recited in claim 1, wherein
the support member includes a second cuff connected to the cuff
for receiving the thumb at an edge opposite the accelerometer, the second cuff
receiving a heel of the thumb and a corresponding dorsal section of a hand therein.

9. The apparatus as recited in claim 8, wherein
the support member is formed from semi-rigid material and
extends over a metacarpophalangeal joint of the thumb on the palm side of the
thumb.

10. The apparatus as recited in claim 1, wherein
the support member further comprises
an adjustable support member traversing at least a portion
of a palm of the hand; and
a finger support member that selectively receives at least
one of the ring finger and little finger therein, wherein the adjustable support
member is coupled between the cuff and the finger support and maintains the at
least one of the ring finger and little finger in a predetermined position relative to
the thumb.

11. The apparatus as recited in claim 10, wherein
the adjustable support member includes
a first curvilinear member having a plurality of tabs
extending from a side of the first curvilinear member opposite a side contacting a
palm of the patient; and
a second member having a plurality of recesses extending therethrough for receiving a respective one of the plurality of tabs therein enabling the apparatus to be adjusted to fit patients having different sized hands.

12. The apparatus as recited in claim 1, wherein the support member further comprises
   a curvilinear member traversing at least a portion of a palm of the hand; and
   a finger support member that is selectively receives at least one of the ring finger and little finger therein, wherein the adjustable support member is coupled between the cuff and the finger support and maintains the at least one of the ring finger and little finger in a predetermined position relative to the thumb.

13. The apparatus as recited in claim 12, wherein the finger support member is retained at substantially a tip end of the at least one of the ring finger and little finger, and further comprising
   a second accelerometer that generates an electrical signal indicative of movement of the at least one of ring finger and little finger for use in determining a neuromuscular transmission value indicative of an effectiveness of the neuromuscular blocking agent.

14. The apparatus as recited in claim 1, wherein the apparatus determines a neuromuscular transmission value for a patient under an effect of a neuromuscular blocking agent and the determined neuromuscular transmission value is indicative of an effectiveness of the neuromuscular blocking agent.

15. A method of determining a neuromuscular transmission value for a patient under comprising the activities of:
   retaining an accelerometer at tip of a thumb of the patient;
   supporting the thumb of the patient using a support member to maintain the thumb in a predetermined position and restricting movement of the thumb from the predetermined position;
applying a stimulus to a nerve of a patient causing the thumb to exert a force on the support member and move from the predetermined position; measuring the movement of the thumb from the predetermined position using the accelerometer; and determining a neuromuscular transmission value for the patient using the measured movement of the thumb.

16. The method as recited in claim 15, further comprising the activities of
   retaining a second accelerometer at substantially a tip end of at least one of the ring finger and little finger of the patient; and measuring the movement of at least one of the ring finger and little finger using the second accelerometer in response to said activity of applying a stimulus to the nerve; and determining the neuromuscular transmission value for the patient using at least one of the measured movement of the thumb and measured movement of the at least one of the ring finger and little finger.

17. The method as recited in claim 15, further comprising the activities of
   retaining a temperature sensor at a substantially fixed position on a palm of the hand of the patient;
   sensing a skin temperature using the temperature sensor; and using the sensed skin temperature to determine whether the determined neuromuscular transmission value is valid.

18. The method as recited in claim 15 further comprising the activities of determining a neuromuscular transmission value for a patient under an effect of a neuromuscular blocking agent, the determined neuromuscular transmission value being indicative of an effectiveness of the neuromuscular blocking agent.
19. A system for determining a neuromuscular transmission value comprising:

   an adapter selectively positionable on a hand of a user that supports a thumb in a predetermined position and restricts movement of the thumb, the adapter including

   an accelerometer positioned on the adapter at substantially a tip of the thumb, and

   a stimulation mechanism positioned that applies a stimulus to a nerve that causes the thumb to move from the predetermined position in a direction towards a palm of the hand, wherein the accelerometer generates an electrical signal including data indicative of movement of the thumb;

   a measurement device that calculates a neuromuscular transmission value associated with a patient, the measurement device including

   a control processor coupled to the stimulation mechanism that signals the stimulation mechanism to apply the stimulus to the nerve; and

   a measurement processor, coupled to the accelerometer that receives the electrical signal indicative of thumb movement from the accelerometer and calculates the neuromuscular transmission value for the patient using thumb movement data; and

   a communication processor coupled to the measurement processor that communicates the calculated neurotransmission value to a healthcare professional.

20. The system as recited in claim 19, wherein

   the adapter further comprises a second accelerometer retained by the adapter at substantially a tip end of at least one of a ring finger and little finger on the hand of the patient, said second accelerometer generates an electrical signal including data indicative of movement of at least one of the ring finger and little finger in response to application of the stimulus by the stimulation mechanism.

21. The system as recited in claim 20, wherein

   said measurement processor receives data indicative of movement of at least one of the ring finger and litter finger and uses the data indicative of movement of the at least one of the ring finger and littler finger in conjunction
with the thumb movement data to calculate a composite neurotransmission value for the patient.

22. The system as recited in claim 21, wherein said measurement processor assigns a weight to each of the thumb movement data and data indicative of movement of at least one of the ring finger and little finger to and calculates the composite neurotransmission value using the weighted values.

23. The system as recited in claim 19, further comprising a temperature sensor coupled to the adapter for sensing a skin temperature indicative of a rate of blood flow through the thumb.

24. The system as recited in claim 23, wherein the measurement processor receives data representing sensed skin temperature from the temperature sensor, compares the sensed skin temperature to a threshold range of acceptable temperature values and, in response to determining the sensed skin temperature is outside the threshold range, indicating the calculated neurotransmission value is invalid.

25. The system as recited in claim 24, wherein in response to the indication that the calculated neurotransmission value is invalid, the control processor controls the stimulation mechanism to re-stimulate the nerve and the measurement processor to re-calculate an updated neurotransmission value for the patient.

26. The system as recited in claim 19, wherein said control processor determines a current stage of a procedure being performed on a patient and automatically controls the measurement processor to measure the neuromuscular transmission value based on the determined current stage of the procedure.

27. The apparatus as recited in claim 19, wherein the system determines a neuromuscular transmission value for a patient under an effect of a
neuromuscular blocking agent and the determined neuromuscular transmission value is indicative of an effectiveness of the neuromuscular blocking agent.

28. A method of identifying a neuromuscular transmission value comprising the activities of:

   positioning an adapter on a hand of a patient to support a thumb in a predetermined position and restricts movement of the thumb, the adapter includes an accelerometer positioned on the adapter at substantially a tip of the thumb;

   applying, by a stimulation mechanism, a stimulus to a nerve of the patient causing the thumb to move from the predetermined position in a direction towards a palm of the hand in response to a control signal generated by a control processor,

   generating an electrical signal including data indicative of movement of the thumb sensed by the accelerometer;

   receiving, by a measurement processor, the electrical signal indicative of thumb movement from the accelerometer;

   calculating the neuromuscular transmission value for the patient using thumb movement data; and

   communicating data representing the neurotransmission value for the patient to paralysis to a healthcare professional.

29. The method as recited in claim 28, wherein

   the adapter includes a second accelerometer retained by the adapter at substantially a tip end of at least one of a ring finger and little finger on the hand of the patient, and further comprising the activity of

   generating, by the second accelerometer, an electrical signal including data indicative of movement of at least one of the ring finger and little finger in response to application of the stimulus by the stimulation mechanism.

30. The method as recited in claim 29, further comprising the activities of

   receiving data indicative of movement of at least one of the ring finger and litter finger;
calculating a composite neurotransmission value for the patient using the data indicative of movement of the at least one of the ring finger and littler finger in conjunction with the thumb movement data.

31. The method as recited in claim 30, further comprising the activity of

assigning a weight, by the measurement processor, to each of the thumb movement data and data indicative of movement of at least one of the ring finger and little finger; and

calculating the composite neurotransmission value using the weighted values.

32. The method as recited in claim 28, further comprising the activities of

sensing, via a temperature sensor, a skin temperature indicative of a rate of blood flow through the thumb; and

receiving, by the measurement processor, data representing sensed skin temperature from the temperature sensor;

comparing the sensed skin temperature to a threshold range of acceptable temperature values; and

in response to determining the sensed skin temperature is outside the threshold range, indicating the calculated neurotransmission value is invalid

33. The method as recited in claim 32, wherein

in response to the indication that the calculated neurotransmission value is invalid, further comprising the activity of

controlling the stimulation mechanism, by the control processor, to re-stimulate the nerve and the measurement processor to re-calculate an updated neurotransmission value for the patient.

34. The method as recited in claim 28, further comprising the activity of

determining, by the control processor, a current stage of a procedure being performed on a patient and automatically controlling the
measurement processor to measure the neuromuscular transmission value based on the determined current stage of the procedure.

35. The method as recited in claim 28 further comprising the activities of
determining a neuromuscular transmission value for a patient under an effect of a neuromuscular blocking agent, the determined neuromuscular transmission value being indicative of an effectiveness of the neuromuscular blocking agent.
positioning an adapter on a hand of a user and maintains the least one of (a) a thumb; (b) ring finger and (c) a little finger in a first pre-loaded position.

determining and/or identifying a stage of a procedure being performed on a patient and selecting an NMT calculation algorithm associated with the identified stage.

Controlling the nerve stimulator (1012 in Fig. 10) to generate a signal causing the at least one electrodes (1011 in Fig. 10) to apply a stimulus to the peripheral nerve on which they are positioned resulting in the movement of at least one of (a) thumb; (b) ring finger and (c) little finger in their natural opposable trajectory from an initial pre-loaded position first positioned.

sensing the physical motion associated with the movement of the at least one (a) thumb; (b) ring finger; and (c) little finger and converting the physical motion to electrical signals.

sense a temperature of the skin for use in determining whether the blood flow to the thumb is sufficient.

Receiving data representing motion of the thumb and/or motion of the little/ring finger generated by any of the first and second accelerometers, respectively and the data representing the skin temperature.

determining the type and source of the data received.

Calculating an NMT value for the patient based on the type and source of the data received.

NMT value valid?

yes

Providing NMT Value to a healthcare professional for review and analysis thereof.

no

recalculate the NMT value.

Providing notification of potential problems due to invalid NMT value.

Fig. 11
Retaining an accelerometer at substantially a tip end of a patient's thumb

Supporting the thumb of the patient using a support member to maintain the thumb in a predetermined position and restrict movement of the thumb from the predetermined position

Applying a stimulus to a nerve of a patient causing the thumb to exert a force on the support member and move from the predetermined position

measuring the movement of the thumb from the predetermined position using the accelerometer

a neuromuscular transmission value is determined for the patient using the measured movement of the thumb

Fig. 12
A. CLASSIFICATION OF SUBJECT MATTER

INV. A61B5/11 A61B5/22

ADD.

According to International Patent Classification (IPC) and national classification

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61B G06F A61M

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C.

See patent family annex.

Date of the actual completion of the international search

22 January 2013

Date of mailing of the international search report

30/01/2013

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