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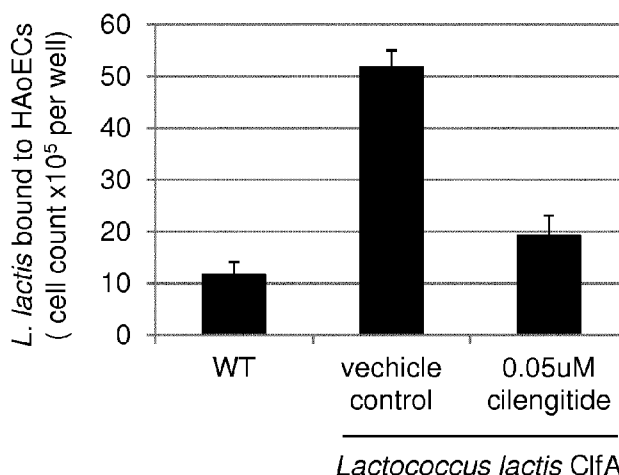
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(54) **Title:** A METHOD OF TREATING OR PREVENTING SEPSIS

Figure 6.**B.**

(57) **Abstract:** Use of a $\alpha V\beta 3$ antagonist such as cilengitide or a functional variant thereof for the treatment or prevention of sepsis in a patient is described, in which the cilengitide is delivered to the patient intravenously.

Title

A method of treating or preventing sepsis

Technical Field

- 5 The invention relates to a method for the treatment or prevention of sepsis. In particular, the invention relates to a method for preventing or inhibiting the development of sepsis, severe sepsis or septic shock in a patient with a bacterial infection of the blood.

Background to the Invention

- 10 Currently there are no approved specific treatments for the underlying pathophysiology of sepsis and therefore the management plan focuses on reducing the infection through use of aggressive intravenous antibiotic therapy often delivered in high concentrations for long periods of time. The use of antibiotics in the treatment of sepsis is not a reliable long term solution due to the rapid global emergence of antibiotic resistant strains of bacteria. According
15 to the most recent report on antimicrobial resistance by the World Health Organisation a 'post-antibiotic' era is imminent, suggesting that the use of antibiotics in sepsis will shortly come to an abrupt end. Upon suspicion of developing sepsis, treatment with antibiotics should begin immediately, preferably within the first six hours or earlier. Initially the patient will receive broad-spectrum antibiotics, which are effective against a variety of bacteria. These antibiotics
20 include gentamycin, cefepime, piperacillin or meropenem. Once a blood culture comes back positive for identification of the specific type of bacteria (Gram negative or Gram positive) the following antibiotics may be administered. Gram negative: amikacin or tobramycin, Gram positive: vancomycin. All antibiotics are administered intravenously.

- Animal models of sepsis have been developed in an effort to create reproducible systems for
25 studying the disease progression, pathogenesis and preliminary testing of potential therapeutic agents. However, demonstrated benefit from a therapeutic agent in animal models of sepsis has rarely been translated into success in human clinical trials. Xigris for example has recently been withdrawn from the market due to limited efficacy. Several reasons could account for these failures but most prominent is the application of theory based on incorrect or incomplete
30 observations in the animal models. Typically, animals (mice in particular) do not develop sepsis unless forced by delivering high levels of non-commensal bacteria. Due to the lack of applicability of animal models, researchers have focused the interaction between bacteria and

human blood and endothelial cells, however significant questions about the approach to investigating these interactions have been raised.

No group to date has considered $\alpha V\beta 3$ antagonists.

- 5 A publication by Pranita P. Sarangi, *et al.*, (SHOCK, vol. 38, no. 2, 1 August 2012), investigated the effect of an RGD peptide on beta-1-integrin in a mouse model of endotoxemia and sepsis. This disclosure differs from the current invention at least in that the RGD peptide utilised by the authors was not an $\alpha V\beta 3$ antagonist.
- 10 C.C. Hsu, *et al.*, (Journal of Thrombosis and Haemostasis, vol.9, no. 3, 1 March 2011) investigated the effect of rhodostomin on LPS-induced endotoxemia in a mouse model. This publication is not concerned with methods to prevent or inhibit the early development of sepsis in an individual and there is no discussion as to the use of a $\alpha V\beta 3$ antagonist. The $\alpha V\beta 3$ antagonist of the current invention works by preventing the adhesion of bacteria to endothelial
- 15 cells. The model utilised by the authors of Hsu *et al.*, involves isolated LPS and not bacteria and, as such, Hsu *et al.*, has not demonstrated the effects of a $\alpha V\beta 3$ antagonist in sepsis, in particular in early sepsis, as the bacteria itself is not present. Furthermore, the model utilised by Hsu *et al.*, is not a model for early sepsis or developing sepsis which does not involve LPS overload.

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It is an object of the invention to overcome at least of the above-referenced problems.

Brief Description of the Invention

- The Applicant has discovered that human vascular endothelial cells under shear conditions
- 25 upregulate the expression of certain extracellular receptors, including the $\alpha V\beta 3$ integrin receptor. In addition, the Applicant has discovered that the human pathogens *Staphylococcus aureus* and *Escherichia.coli* bind to human vascular endothelial cells under shear conditions through the interaction with the vascular endothelial $\alpha V\beta 3$ integrin receptor. In particular, *S. Aureus* clumping factor A binds to fibrinogen which is crosslinked to $\alpha V\beta 3$, and *E.coli*
- 30 liposolysaccharide (LPS) binds directly $\alpha V\beta 3$. The inventors have now found that in fact *Escherichia coli* outer membrane protein A binds to the endothelial cell major integrin, $\alpha V\beta 3$. The Applicant has also discovered that blocking the receptor with a $\alpha V\beta 3$ antagonist such as cilengitide causes a dose-dependent reduction in adhesion of both gram positive and gram negative bacteria to vascular endothelial cells. As bacterial adhesion to vascular endothelial

cells is a critical event in the development of bacterial sepsis, in particular the progression of blood infection to sepsis, severe sepsis and septic shock, the invention relates to the treatment or prevention of sepsis by administration, ideally intravenous administration, of a $\alpha V\beta 3$ antagonist to a patient. Moreover, as blocking the vascular endothelial $\alpha V\beta 3$ integrin with a $\alpha V\beta 3$ antagonist causes a reduction in adhesion of both gram positive and gram negative bacteria, the therapeutic intervention does not require blood cultures to be measured in advance and can be initiated as soon a blood infection is suspected or has been detected.

Accordingly, the invention relates to the use of a functional $\alpha V\beta 3$ antagonist for the treatment or prevention of sepsis in a patient, in which the functional $\alpha V\beta 3$ antagonist is preferably delivered to the patient intravenously.

In one embodiment, the functional $\alpha V\beta 3$ antagonist is a potent inhibitor of the $\alpha V\beta 3$ receptor. In one embodiment, the functional $\alpha V\beta 3$ antagonist is specific for the αV domain. In one embodiment, the functional $\alpha V\beta 3$ antagonist is a peptide. In one embodiment, the peptide is a cyclic peptide. In one embodiment, the cyclic peptide is selected from cilengitide and cilengitide variants.

In one embodiment, the functional $\alpha V\beta 3$ antagonist is an antibody or fragment thereof. In one embodiment, the antibody or fragment is specific for the αV domain. In one embodiment, the antibody is a monoclonal antibody. In one embodiment, the antibody is human or humanised. In one embodiment, the antibody is a nanobody.

In one embodiment, the $\alpha V\beta 3$ antagonist is a low molecular weight antagonist. Examples of low molecular weight $\alpha V\beta 3$ antagonists are peptides such as cilengitide and peptidomimetics such as IS201.

In one embodiment, the patient has, or is suspected of having, a bacterial infection of the blood.

In one embodiment, the use of the invention is specifically for early prevention or inhibition of the development of sepsis in a patient having or suspected of having a bacterial infection of the blood.

In one embodiment, the use of the invention is specifically for early prevention or inhibition of the development of severe sepsis or septic shock in a patient having or suspected of having sepsis or an infection of the blood.

- 5 In one embodiment, the use of the invention is specifically for treatment of severe sepsis or septic shock in a patient.

In one embodiment, the use of the invention additionally comprises treatment with an intervention selected from: intravenous antibiotics; intravenous fluids; and organ-specific
10 intervention.

In one embodiment, a dosage of less than $10\text{mg}/\text{m}^2$ is administered to the patient. In one embodiment, a dosage of less than $1\text{mg}/\text{m}^2$ is administered to the patient.

- 15 The invention also relate to a pharmaceutical composition comprising a therapeutically effective amount of a functional $\alpha\text{V}\beta 3$ antagonist and an antibiotic typically formulated for intravenous delivery. In one embodiment, the antibiotic is a broad spectrum antibiotic. Examples include gentamycin, cefepime, piperacillin or meropenem. In one embodiment, the antibiotic is a gram-negative specific antibiotic. Examples include amikacin or tobramycin. In
20 one embodiment, the antibiotic is a gram-positive specific antibiotic. Examples include vancomycin. In one embodiment, the pharmaceutical composition comprises less than $10\text{mg}/\text{m}^2$. In one embodiment, a dosage of less than $1\text{mg}/\text{m}^2$ is administered to the patient.

- A further aspect of the invention relates to a method of treating or preventing sepsis in a patient,
25 comprising intravenously administering a functional $\alpha\text{V}\beta 3$ antagonist as described herein. In an embodiment, the method is for early prevention or inhibition of the development of sepsis in a patient having or suspected of having a bacterial infection of the blood. In an embodiment, the method is for early prevention or inhibition of the development of severe sepsis or septic shock in a patient having or suspected of having sepsis. In an embodiment, the method is for
30 treatment of severe sepsis or septic shock in a patient.

Brief Description of the Figures

Figure 1. *The effect of shear and conditions necessary for bacterial binding to Human endothelial cells.* Human endothelial cells were grown either statically (**A**) or under physiological shear conditions of 10dynes/cm² (**B**). *S. aureus* were allowed to adhere to the sheared human endothelial cells in the absence or presence of human plasma (**C**) and/or in the absence (**D**) or presence (**E**) of tumour necrosis factor alpha (TNF α). Once these conditions were established we investigated the ability of *S. aureus* to bind to human endothelial cells under static or shear conditions in the presence of plasma and TNF α (**F**). Our results indicate that *S. aureus* binds significantly more to sheared human endothelial cells in the presence of plasma and TNF α .

Figure 2. *Identification of the major cell wall protein on *S. aureus* that binds to sheared human endothelial cells.* *S. aureus* bound to human endothelial cells in the presence of human plasma and TNF α . Using a strain deficient in expression of the protein A expressed on the bacteria surface failed to affect *S. aureus* binding, however using a strain deficient in expression of the major cell wall protein clumping factor A significantly reduced binding (**A**). Dot blots were used to confirm the lack of expression of protein A and Clumping factor A (**B**). *L. lactis* is an excellent surrogate host previously used for determining function of *S. aureus* proteins of interest. Over expression of protein A in surrogate host *L. lactis* failed to restore binding to the human endothelial cells. Over expression of clumping factor A in surrogate host *L. lactis* significantly increased binding to the human endothelial cells (**C**). Dots blots were used to confirm over expression of ClfA and protein A respectively (**D**). These results suggest that the major cell wall protein ClfA is critical for *S. aureus* binding to human endothelial cells.

Figure 3. *Identification of the role of human plasma proteins in *S. aureus* Clumping factor A binding to human endothelial cells.* *L. lactis* expressing ClfA binding to human endothelial cells was significantly reduced when ClfA plasma proteins were removed (**A**). Addition of IgG only failed to reinstate *L. lactis* ClfA binding to the human endothelial cells. Addition of fibrinogen only completely restored *L. lactis* binding to the human endothelial cells (**B**). Deletion of the amino acids in ClfA (**C**) critical for fibrinogen binding significantly reduced the interaction with the human endothelial cells (**D**). These results suggest that fibrinogen is key for ClfA to crosslink and bind to the human endothelial cells.

Figure 4. *Intracellular calcium release in human endothelial cells as a result of ClfA/fibrinogen binding.* Uninfected resting human endothelial cells do not release intracellular calcium (**A and D**). However upon ClfA / fibrinogen binding to the human endothelial cells there is a spike in calcium release at around 4 minutes post infection (**B and D**). Using a strain deficient in expression of ClfA failed to trigger the intracellular signal that results in calcium release (**C and D**). These results suggest that following ClfA / fibrinogen binding to human endothelial cells an intracellular signal is generated.

Figure 5. *Mobilisation of the Weibel Palade bodies and secretion of vonWillebrand factor following ClfA/Fibrinogen binding.* Uninfected resting human endothelial cells (**A and D**) or *L. lactis* mock transfected cells (**B and D**) do not mobilise the Weibel Palade bodies or secrete vonWillebrand factor onto the surface of the endothelial cells. Over expression of ClfA in *L. lactis* led to mobilisation of the Weibel Palade bodies and secretion of vWf onto the surface of human endothelial cells (**C and D**).

Figure 6. *Identification of the endothelial cell receptor that recognises *S. aureus* ClfA and fibrinogen that mediated the interaction.* Upon activation with low concentration TNF α human endothelial cells α V β 3 is significantly upregulated (**A**). Binding of *L. lactis* expressing ClfA was significantly reduced following pretreatment of the human endothelial cells with an inhibitor of α V β 3, cilengitide (**B**). Pretreating the purified receptor α Vb3 with cilengitide also significantly inhibited *L. lactis* ClfA from binding (**C**). These results suggest that α V β 3 is the receptor responsible for binding to fibrinogen and crosslinking to *S. aureus* ClfA.

Figure 7. *In vivo, venous mesenteric perfusion model to demonstrate that bacterial adhesion to endothelial cells is inhibited by cilengitide.* Wildtype *S. aureus* adhered to activated murine endothelial cells (**A**). Using a strain deficient in expression of ClfA significantly adhered less to the endothelial cells (**B and D**). *S. aureus* failed to significantly bind murine endothelial cells in the presence of cilengitide administered intravenously (**C and E**).

Figure 8. *The effect of *S. aureus* on human endothelial cell proliferation.* Human endothelial cells proliferate over 24 hrs in growth media (**C and F**). Addition of *S. aureus* to the endothelial cells significantly reduced human endothelial cell proliferation over a 24hr period (**D and G**). Using a strain deficient in expression of ClfA significantly recovered the ability of *S. aureus* to

inhibit human endothelial cell proliferation (**E**). Equally, addition of cilengitide to the human endothelial cells also significantly recovered the ability of *S. aureus* to inhibit proliferation (**H**).

Figure 9. *The effect of S. aureus on human endothelial cell apoptosis.* Based on the observation that *S. aureus* inhibits human endothelial cell proliferation we investigated if this is due to apoptosis. Healthy human endothelial cells have low levels of apoptosis, however addition of *S. aureus* significant apoptosis is observed. Using a strain deficient in expression of ClfA significantly reduced the apoptosis induced by *S. aureus* (**A**). Addition of cilengitide to the human endothelial cells also significantly reduced the ability of *S. aureus* to induce apoptosis (**B**).

Figure 10. *The effect of S. aureus on human endothelial cell permeability.* If human endothelial cells are becoming apoptotic it may lead to break down in barrier function. Uninfected human endothelial cells form tight junctions that prevents passage of fluid through the endothelial layer. Addition of *S. aureus* disrupts this barrier and results in significant passage of fluid across the monolayer of cells. Using a strain deficient in expression of ClfA significantly reduced this disruption in barrier permeability. Similarly, addition of cilengitide to the human endothelial cells also significantly reduced the amount of permeability of the barrier following *S. aureus* infection.

Figure 11. *Model of the S. aureus interaction with human endothelial cells.* *S. aureus* clumping factor A binds soluble plasma fibrinogen. This in turn crosslinks the bacteria to aVb3 expressed on endothelial cells. Once bound an intracellular signal is generated which results in a significant rise in calcium and secretion of vonWillebrand factor. Additional signals result in loss of proliferation, induced apoptosis and increased vascular permeability. Together these changes cause dysregulation of normal endothelial cell function. Addition of cilengitide significantly reduces all of these dysfunctional messages.

Figure 12. Addition of cilengitide does not cause toxicity in human endothelial cells.

Figure 13. *Escherichia coli binding to sheared Endothelial cells under static conditions.* Endothelial cells were sheared to replicate the physiological state they find themselves in the human vasculature. Endothelial cells were fixed, permeabilized and incubated with antibody against a-actin (primary) and Alexa Fluor® 488-conjugated (secondary). Nuclei were stained

with DAPI. Images were acquired with a fluorescence microscopy. Images are representative of three independent experiments. Endothelial cells grown under static conditions display random orientation (**A**); whereas for endothelial cells grown under shear conditions display alignment in the direction of the flow (**B**). Consistent with this it was demonstrated that VE-cadherin expression determined by western blot of protein homogenates from static and sheared endothelial cells is upregulated in sheared endothelial cells (**C**). 9 clinical strains of *E. coli* were tested for their ability to bind to sheared endothelial cells and all strains bound to varying degrees (**D**). *E. coli* strain CFT073 was used as the representative strain in all experiments. Consistent with previous observations *S. aureus* (control) requires plasma in order to successfully bind to the sheared endothelial cells however *E. coli* appears to bind in the absence or presence of a plasma protein. These data suggest that *E. coli* is capable of binding to sheared endothelial cells in the absence of plasma proteins this is in contrast to *S. aureus* binding to endothelial cells which is dependent on plasma proteins.

Figure 14. *Escherichia coli* binds to the major integrin $\alpha V\beta 3$ expressed on endothelial cells

The effect of inhibition of $\alpha V\beta 3$ integrin on binding of *E. coli* to endothelial cells was investigated. The results demonstrate that the selective $\alpha V\beta 3$ integrin inhibitor, cilengitide (0.05 μ M) significantly inhibited *E. coli* binding to endothelial cells using a static assay (**A**) or when *E. coli* are perfused over the sheared endothelial cells at 10dyns for 5 minutes (**B**). These results demonstrate that *E. coli* binding to endothelial cells was inhibited by cilengitide.

Figure 15. *Escherichia coli* outer membrane protein A binds to the endothelial cell major integrin, $\alpha V\beta 3$.

Using a strain deficient in LPS it was found that binding to the endothelial cells was unaffected, suggesting that LPS is not the component responsible for anchoring the bacteria to the endothelial cells (**A**). To investigate if trypsin sensitive proteins were responsible for binding to endothelial cells, the cells were pre-treated with trypsin and binding was significantly reduced (**B**). A bioinformatic approach was used to search the *E. coli* genome for surface proteins that contain an RGD sequence. Almost 20 proteins with an RGD or KGD sequence were identified however only 10 were expressed on the cell surface (**E**). Outer membrane protein A ompA was deleted from the parent strain CFT073 and re-introduced into the knockout to elate concerns about pleiotropic effects. The strain deficient in expression of ompA was significantly reduced in its ability to bind to the endothelial cells using both a static assay (**C**) or when the bacteria were perfused over the sheared endothelial cells (**D**). Binding

was restored when the complimented strain was used, suggesting that ompA play a key role in binding to the endothelial cells (C+D). These results demonstrate that outer membrane protein A is ubiquitously expressed on the surface *E. coli* strains and expresses the integrin recognition motif RGD. Deletion of ompA significantly reduces the ability of *E. coli* from binding to the endothelial cells.

Figure 16. *Escherichia coli* ompA binding to $\alpha V\beta 3$ leads to an increase in permeability in endothelial cells. One of the characteristic signs of sepsis is increased vascular permeability. The effect of binding of *E. coli* to endothelial cells on permeability was investigated. Upon *E. coli* binding, there was a 30% increase in permeability and the strain deficient in ompA significantly reduces permeability. Addition of the complimented ompA strain resulted in an increase in permeability which is comparable to the parent *E. coli* control. Most importantly, *E. coli* induced increase in permeability was significantly reduced permeability following preincubation $\alpha V\beta 3$ results in a signal that triggers an increase in fluid leakage and permeability. These data illustrate that *E. coli* binding to endothelial cells results in a significant increase in permeability (~30%). Using a strain deficient of ompA or preincubating the endothelial cells with cilengitide significantly reduces permeability.

Figure 17. *Escherichia coli* ompA binding to $\alpha V\beta 3$ results in loss of tight junction protein and increase in apoptosis. An increase in permeability is due to a separation of the endothelial cells. To investigate, tight junction formation was assessed. Immunostaining for VE-cadherin demonstrated tight junction formation in the absence of infection (A) however there was a loss of connections following *E. coli* infection (B). Using the strain deficient in ompA recovered the VE-cadherin tight junction formation (C). The complimented strain also significantly led to loss of tight junction formation (D). Finally pre-treating the endothelial cells with cilengitide also led to recovery of tight junction formation following *E. coli* infection (E). It was also investigated if the loss of tight junction formation was due to apoptosis. To determine this, Annexin V exposure on the cell surface, a hall mark of apoptotic cells, was assessed by flow cytometry. Uninfected endothelial cells have a low level of apoptosis, however upon addition of *E. coli* to the endothelial cells, apoptosis was significantly increased. Addition of *E. coli* Δ ompA caused a significantly lower extent of apoptosis in the endothelial cells (F). Addition of the complimented ompA strain also induced apoptosis comparable to the *E. coli* control. Preincubation of endothelial cells with cilengitide led to a significant reduction in *E. coli*

induced apoptosis. Addition of cilengitide alone to the endothelial cells failed to affect to the viability of cells. These data demonstrate that *E. coli* binding to sheared endothelial cells results in separation of the endothelial cells resulting in increased permeability and that ompA binding to $\alpha V\beta 3$ generates a signal resulting in programmed cell death (apoptosis).

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Detailed Description of the Invention

Definitions:

“ $\alpha V\beta 3$ ” is a member of the integrin supergene family of cell surface glycoprotein receptors that promote cellular adhesion. It binds to a variety of plasma and extracellular matrix proteins containing the conserved RGD amino acid sequence and modulates cell adhesion. It is highly expressed in osteoclasts where it plays a role in bone resorption, and is also abundant in vascular smooth muscle cells and endothelial cells, and in some tumour cells, where it is involved in angiogenesis and cell migration (Felding et al, Curr Opin Cell Biol. 1993;5;864-868). “vascular endothelial $\alpha V\beta 3$ ” refers to the $\alpha V\beta 3$ integrin expressed by vascular endothelial cells.

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“ αV domain” refers to the αV domain of the vascular endothelial $\alpha V\beta 3$ integrin. The sequence of human vascular endothelial αV domain is provided in SEQUENCE ID NO: 1:

20 *ITAV_HUMAN Integrin alpha-V OS=Homo sapiens (SEQUENCE ID NO: 1)*

MAFPFRRRLRLGPRGLPLLLSGLLLPLCRAFNLDVDSPA EYSGPEGSYFGFAVDFFVP
 SASSRMFLLVGAPKANTTQPGIVEGGQVLKCDWSSTRRCQPIEFDATGNRDYAKDD
 PLEFKSHQWFGASVRSKQDKILACAPLYHWRTEMKQEREPVGTCTFLQDGTCTVEYA
 PCRSQDIDADGQGFCQGGFSIDFTKADRVLLGGPGSFYWQGQLISDQVAEIVSKYDP
 25 NVYSIKYNNQLATRTAQAIFDDSYLGYSVAVGDFNGDGIDDFVSGVPRAARTLGMV
 YIYDGKNMSSLYNFTGEQMAAYFGFSVAATDINGDDYADVFIGAPLFMDRGSDGKL
 QEVGQVSVSLQRASGDFQTTKLNGFEVFARFGSAIAPLGDLQDGFNDIAIAAPYGG
 EDKKGIVYIFNGRSTGLNAVPSQILEGQWAARSMPPSFGYSMKGATDIDKNGYPDLI
 VGAFGVDRAILYRARPVITVNAGLEVYPSILNQDNKTCSLPGTALKVSCFNVRFLK
 30 ADGKGVLPRLNLFQVELLLDKLKQKGAIRRALFLYSRSPSHSKNMTISRGGMLMQCEE
 LIAYL RDESEFRDKLTPITIFMEYRLDYRTAADTTGLQPILNQFTPANISRQAHILLDC
 GEDNVCKPKLEVSVSDSQKKIYIGDDNPLTLIVKAQNGEGAYEAEIVSIPLQADFI
 GVVRNNEALARLSCAFKTENQTRQVVCDLGNPMKAGTQLLAGLRFSVHQQSEMDT

SVKFDLQIQSSNLFDKVSPVVSHKVDLAVLA AVEIRGVSSPDHVFLPIPNWEHKENPE
TEEDVGPVVQHIYELRNNGPSSFSKAMLHLQWPYKYNNNTLLYILHYDIDGPMNCT
SDMEINPLRIKISSLQTTEKNDTVAGQGERDHLITKRDLALSEGDIHTLGCGVAQCLKI
VCQVGRLLDRGKSAILYVKSLLWTETFMNKENQNHSSYSLKSSASFNVIEFPYKNLPIE
5 DITNSTLVTNTVTWGIQPAPMPVPVWVILAVLAGLLLLAVLVFVMYRMGFFKRVRP
PQEEQEREQLQPHENGEGNSET

“β3 domain” refers to the β3 domain of the vascular endothelial αVβ3 integrin. The sequence of human vascular endothelial β3 domain is provided in SEQUENCE ID NO: 2:

ITB3_HUMAN Integrin beta-3 OS=Homo sapiens (SEQUENCE ID NO: 2)

MRARPRRPLWATVLAALGALAGVGVGPNICTTRGVSSCQQCLAVSPMCAWCSDE
ALPLGSPRCDLKENLLKDNCAPESIEFPVSEARVLEDRPLSDKSGSDSSQVTQVSPQRI
ALRLRPDDSKNFSIQVRQVEDYPVDIYYLMDLSYSMKDDLWSIQNLGTKLATQMRK
15 LTSNLRIGFGAFVDKPVSPYMYISPPEALENPCYDMKTTCLPMFGYKHVLTLTLDQVT
RFNEEVKKQSVSRNRDAPEGGFDAIMQATVCDEKIGWRNDASHLLVFTTDAKTHIA
LDGRLAGIVQPNDGQCHVGSDNHYSASTTMDYPSLGLMTEKLSQKNINLIFAVTENV
VNLYQNYSELIPGTTVGVLSDSSNVLQLIVDAYGKIRSKVELEVRLPEELSLSFNA
TCLNNEVIPGLKSCMGLKIGDTSFSIEAKVRGCPQEKEKSFTIKPVGFKDSLIVQVTF
20 DCDCACQAQAEPNSHRCNNGNGTFECGVCRCGPGWLGSQCECSEEDYRPSQQDECS
PREGQPVCSQRGECLCGQCVCHSSDFGKITGKYCECDDFSCVRYKGEMCSGHGQCS
CGDCLCDSDWGTGYCNCCTTRTDTCMSSNGLLCSGRGKCECGSCVCIQPGSYGDTCE
KCPTCPDACTFKKECVECKKFDRGALHDENTCNRYCRDEIESVKELKDTGKDAVNC
TYKNEDDCVVRFFQYYEDSSGKSILYVVEEPEC PKGPDILVLLSVMGAILLIGLAALL
25 IWKLLITIHDRKEFAKFEEERARAKWDTANNPLYKEATSTFTNITYRGT

“αVβ3 antagonist” refers to a molecule that can bind to a αVβ3 integrin. Examples include peptides {cyclic and noncyclic}, non-peptide ligands, disintegrins, peptidomimetics, antibodies, and gene inhibitors. An example of a cyclic peptide is cilengitide. Examples of
30 antibody antagonists are described in the literature, for example US5652110. αVβ3 antagonists are also described in Millard et al {Theranostics 2011; 1:154=188}, Kim et al (Mol Pharm 2013 Oct 7, 3603-3611), Pfaff et al (J Biol Chem 1994; 269, 20233-20238), Healy et al (Biochemistry 1995; 34, 3948-3955), EP2298308 (University of Southern California), Koivunen et al (J Biol Chem 1993;268; 20205-20210 and 1994;124:373-380), Ruoslahti et al

(Annu Rev Cell Dev Biol. 1996; 12:697-715), and Ponce et al (Faseb J. 2001;15;1389-1397). In one embodiment, the $\alpha V\beta 3$ antagonist is selective for αV integrins.

“Functional $\alpha V\beta 3$ antagonist” refers to a $\alpha V\beta 3$ antagonist that can bind to the vascular endothelial $\alpha V\beta 3$ integrin and cause a decrease in binding of *S. aureus* and/or *E. Coli* bacteria to vascular endothelial $\alpha V\beta 3$ integrin in the *in-vitro* binding assay described below. Examples include cilengitide and variants thereof described in EP0770622. It is a routine matter for a skilled person to test the $\alpha V\beta 3$ antagonists described in the literature using the *in-vitro* adhesion assay described below to identify functional $\alpha V\beta 3$ antagonists.

“Cilengitide” is a potent integrin inhibitor for the $\alpha V\beta 3$ receptor. It is a cyclic peptide (cyclo(-RGDf(NMe)V-) which is selective for αV integrins (Jonczyk et al, European Patent Application No: 0770622). The synthesis and activity of the molecule was published in 1999 (Dechantsreiter et al J Med Chem 1999 Aug 12; 42(16)). Cilengitide has been indicated for treatment of cancer (EP2578225, EP2338518, EP2441464).

“Functional variant of Cilengitide” means the variants of cilengitide described in US6001961 which are integrin inhibitors for the $\alpha V\beta 3$ receptor, specifically the cyclic peptides described in Sequence ID NO's 1 to 40 (US6001961, columns 12-13).

“Low molecular weight antagonist” means an antagonist that has a molecular weight of less than 50 KDa. In one embodiment, the low molecular weight antagonist has a molecular weight of less than 20 KDa. In one embodiment, the low molecular weight antagonist has a molecular weight of less than 10 KDa. In one embodiment, the low molecular weight antagonist has a molecular weight of less than 5 KDa. In one embodiment, the low molecular weight antagonist has a molecular weight of less than 4 KDa. In one embodiment, the low molecular weight antagonist has a molecular weight of less than 3 KDa. In one embodiment, the low molecular weight antagonist has a molecular weight of less than 2 KDa. In one embodiment, the low molecular weight antagonist has a molecular weight of less than 1 KDa.

“ $\alpha V\beta 3$ antibody” means an antibody that binds to the $\alpha V\beta 3$ integrin. In one embodiment, the antibody binds specifically to the $\alpha V\beta 3$ or $\alpha V\beta 5$ integrin. In one embodiment, the antibody binds specifically to the $\alpha V\beta 3$ integrin. Examples of $\alpha V\beta 3$ antibodies are described in the literature (Liu et al Drug Dev Res 2008; 69(6) 329-339) and are commercially available, for

example: MAB1976, a mouse monoclonal antibody commercially available from MerckMillipore (Clone LM609), also known as AVASTIN; Vitaxin I, a humanised monoclonal antibody (Coleman et al, Circulation Research 1999; 84; 1268-1276); ABEGGRIN, a derivative of Vitaxin I manufactured by Medimmune; CNTO95, a fully humanised antibody that recognises multiple αV integrins and binds to $\alpha V\beta 3$ or $\alpha V\beta 5$ integrins with high affinity (Trika et al. Int J Cancer 2004;110; 326-335); c7E3 Fab (ABCIXIMAB or REOPRO) and c7E3(Fab')₂, mouse-human chimeric and murine mAb fragments of the parent intact murine mAb 7E3 (Trikha et al. Cancer Res 2002;62;2824-2833 and Varner et al. Angiogenesis 1999;3;53-60); 17E6 antibody (Mitjans et al J Cell Sci 1995; 108; 2825-2838; The term " $\alpha V\beta 3$ antibody" includes antibodies that selectively bind to the αV domain, the $\beta 3$ domain, or both the αV and $\beta 3$ domains. The term "functional $\alpha V\beta 3$ antibody" means an $\alpha V\beta 3$ antibody that binds to the vascular endothelial $\alpha V\beta 3$ integrin and is capable of at least partially blocking adhesion of *S. aureus* or *E.coli* bacteria to endothelial cells in the *in-vitro* adhesion assay described below.

"Disintegrin" means the family of low molecular weight RGD containing cysteine rich peptides derived from viper venoms that can bind to $\alpha V\beta 3$ and block its function. Examples include Trigramin, Kistrin, Bitistatin, Barbourin, Echistatin, Contortrostatin, all described or referenced in Liu et al Drug Dev Res 2008; 69(6) 329-339.

"Peptidomimetics" means compounds containing non-peptidic structural elements that are capable of mimicking the biological actions of peptidic $\alpha V\beta 3$ antagonists. Examples include SC-68448 and SCH221153 both described or referenced in Liu et al Drug Dev Res 2008; 69(6) 329-339, and IS201 described in Bello et al (Neurosurgery 2003;52; 177186).

"Gene inhibitors" means a nucleic acid that can cause reduced expression of $\alpha V\beta 3$. In some embodiments, the agent is a nucleic acid. A nucleic acid agent can be selected from, for example, siRNA, shRNA, miRNA, anti-microRNA, antisense RNA or oligonucleotide, aptamer, ribozyme, and any combinations thereof. When the agent is a nucleic acid, the agent itself can be administered to the subject or a vector expressing/encoding the agent can be administered to the subject. In some embodiments, the vector expressing/encoding the agent is an Adeno-associated virus (AAV) vector.

"Infection of the blood" or "blood infection" means a microbial infection of the blood, for example a bacterial, viral or yeast blood infection. In one embodiment, the term means bacterial

infection of the blood. A patient with a bacterial blood infection is often referred to as “bacteraemic”. In one embodiment, the term means bacterial infection of the blood where the bacteria is a sepsis causing bacteria. In one embodiment, the term means bacterial infection of the blood with a bacterial genus selected from *Staphylococcus*, *Streptococcus*, *Escherichia*,
 5 *Pseudomonas*, *Klebsiella*. In one embodiment, the term means bacterial infection of the blood with a bacterial species selected from *Staphylococcus aureus*, *Streptococcus pyogenes*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Klebsiella spp.* Causative agents of bacterial sepsis are more fully described in Ramachandran et al. (Virulence 2014 Jan 1; 5(1); 213-218).

10 Sepsis is diagnosed when a patient exhibits at least two of the following symptoms, plus a probable or confirmed infection:

- Body temperature above 101 F (38.3 C) or below 96.8 F (36 C)
- Heart rate higher than 90 beats a minute
- Respiratory rate higher than 20 breaths a minute

15

Severe sepsis is diagnosed if the patient also exhibit at least one of the following signs and symptoms, which indicate an organ may be failing:

- Significantly decreased urine output
- Abrupt change in mental status
- 20 • Decrease in platelet count (thrombocytopenia)
- Difficulty breathing
- Abnormal heart pumping function
- Abdominal pain

25 Septic shock is diagnosed if in addition to the symptoms of severe sepsis the patient also displays extremely low blood pressure that doesn't adequately respond to simple fluid replacement.

In this specification, the term “treating” refers to administering a $\alpha V\beta 3$ antagonist to an
 30 individual that has or is suspected of having a blood infection with the purpose to cure, heal, prevent, alleviate, relieve, alter, remedy, ameliorate, or inhibit the development of sepsis, including severe sepsis or septic shock. In a preferred embodiment, the term means preventing or inhibiting the development of sepsis in an individual with a blood infection. In one

embodiment, the patient is administered a therapeutically effective amount of the $\alpha V\beta 3$ antagonist. The term “therapeutically effective amount” refers to the amount of the $\alpha V\beta 3$ antagonist that is required to confer the intended therapeutic effect in the individual, which amount will vary depending on the type of antagonist, route of administration, status of infection or sepsis, and possible inclusion of other therapeutics or excipients. In one embodiment, the therapeutically effective amount is less than $100\text{mg}/\text{m}^2$. “ mg/m^2 ” means mg per m^2 of body surface area, and a method of calculating body surface area is provided at www.halls.md/body-surface-area/bsa.htm. In one embodiment, the therapeutically effective amount is less than $50\text{mg}/\text{m}^2$. In one embodiment, the therapeutically effective amount is less than $10\text{mg}/\text{m}^2$. In one embodiment, the therapeutically effective amount is less than $5\text{mg}/\text{m}^2$. In one embodiment, the therapeutically effective amount is less than $1\text{mg}/\text{m}^2$. In one embodiment, the therapeutically effective amount is 0.001 to $50\text{mg}/\text{m}^2$. In one embodiment the therapeutically effective amount is 0.001 to $10\text{mg}/\text{m}^2$. In one embodiment, the therapeutically effective amount is 0.001 to $1.0\text{mg}/\text{m}^2$. In one embodiment, the therapeutically effective amount is 0.01 to $10\text{mg}/\text{m}^2$. In one embodiment, the therapeutically effective amount is 0.1 to $10\text{mg}/\text{m}^2$. In one embodiment, the therapeutically effective amount is 0.001 to $1.0\text{mg}/\text{m}^2$. In one embodiment, the therapeutically effective amount is 0.01 to $1\text{mg}/\text{m}^2$. In one embodiment, the therapeutically effective amount is 0.1 to $1\text{mg}/\text{m}^2$. In one embodiment, the therapeutically effective amount is administered once daily for a period 2 to 14 days. In one embodiment, the methods and uses of the invention apply especially to patients having or suspected of having a bacterial infection of the blood and for the purpose of inhibiting or preventing the development of sepsis. In another embodiment, the methods and uses of the invention apply to patients that are at risk of bacterial blood infection (i.e. immunocompromised patients, trauma patients, and patients having undergone major surgery such as cardiothoracic surgery) and for the purpose of preventing or inhibiting bacterial infection of the blood. In one embodiment, the methods and uses of the invention apply especially to patients having or suspected of having sepsis and for the purpose of inhibiting or preventing the development of severe sepsis or septic shock. In one embodiment, the method and uses of the invention are for a patient in need thereof. The term “patient in need thereof” refers to a person who has or is suspected of having or developing sepsis. The term “prevention of sepsis” means preventing or inhibiting the development of sepsis in a patient with a blood infection, or preventing or inhibiting the development of severe sepsis in a patient with a sepsis, or preventing or inhibiting the development of septic shock in a patient with severe sepsis.

To practice the methods of this invention, the $\alpha V\beta 3$ antagonist can be administered orally, parenterally, by inhalation spray, topically, rectally, nasally, buccally, vaginally or via an implanted reservoir. The term "parenteral" as used herein includes subcutaneous, intracutaneous, intravenous, intramuscular, intraarticular, intraarterial, intrasynovial, intrasternal, intrathecal, intralesional, and intracranial injection or infusion techniques. A sterile injectable composition, e.g., a sterile injectable aqueous or oleaginous suspension, can be formulated according to techniques known in the art using suitable dispersing or wetting agents (such as Tween 80) and suspending agents. The sterile injectable preparation can also be a sterile injectable solution or suspension in a non-toxic parentally acceptable diluents or solvent for example, as a solution in 1,3-butanediol. Among the acceptable vehicles and solvents that can be employed are mannitol, water, Ringer's solution and isotonic sodium chloride solution. In addition, sterile, fixed oils are conventionally employed as a solvent or suspending medium (eg. Synthetic mono- or diglycerides). Fatty acids, such as oleic acid and its glyceride derivatives are useful in the preparation of injectables, as are natural pharmaceutically-acceptable oils, such as olive oil or castor oil, especially in their polyoxyethylated versions. These oil solutions or suspensions can also contain a long-chain alcohol diluents or dispersant, or carboxymethyl cellulose or similar dispersing agents. Other commonly used surfactants such as Tweens or Spans or other similar emulsifying agents or bioavailability enhancers which are commonly used in the manufacture of pharmaceutically acceptable solid, liquid, or other dosage forms can also be used for the purposes of formulation.

A composition for oral administration can be any orally acceptable dosage form including, but not limited to, capsules, tablets, emulsions and aqueous suspensions, dispersions and solutions. In the case of tablets for oral use, carriers that are commonly used include lactose and corn starch. Lubricating agents, such as magnesium stearate, are also typically added. For oral administration in a capsule form, useful diluents include lactose and dried corn starch. When aqueous suspensions or emulsions are administered orally, the active ingredient can be suspended or dissolved in an oily phase combined with emulsifying or suspending agents. If desired, certain sweetening, flavouring, or colouring agents can be added. A nasal aerosol or inhalation composition can be prepared according to techniques well known in the art of pharmaceutical formulation. A fused multicyclic compound-containing composition can also be administered in the form of suppositories for rectal administration. The carrier in the pharmaceutical composition must be "acceptable" in the sense of being compatible with the active ingredient of the formulation (and preferable, capable of stabilising it) and not

deleterious to the subject to be treated. For example, one or more solubilising agents, which form more soluble complexes with the fused multicyclic compounds, or more solubilising agents, can be utilised as pharmaceutical carriers for delivery of the active compounds. Examples of other carriers include colloidal silicon dioxide, magnesium stearate, sodium lauryl sulphate, and D&C Yellow #10.

“Antibody” refers to an intact $\alpha V\beta 3$ -binding immunoglobulin in any form, including but not limited to monoclonal, polyclonal, humanized or human form, or antibody fragments that bind to $\alpha V\beta 3$. The term includes monoclonal or polyclonal $\alpha V\beta 3$ -binding fragments with the Fc (crystallizable fragment) region or FcRn binding fragment of the Fc region, referred to herein as the “Fc fragment” or “Fc domain”. In one embodiment, the antibody has the Fc region removed or modified such that it cannot interact with Protein A of bacteria. Methods of making such antibodies are described in Hay et al (Immunochemistry 12(5):373-378), Parkham et al (J. Immunol 1983;131(6):2895-2902) and Baldwin et al (J. Immunol Methods 1989 121(2): 209-217). $\alpha V\beta 3$ -binding fragments may be produced by recombinant DNA techniques or by enzymatic or chemical cleavage of intact antibodies. $\alpha V\beta 3$ -binding fragments include, inter alia, Fab, Fab', F(ab')₂, Fv, dAb, and complementarity determining region (CDR) fragments, single-chain antibodies (scFv), single domain antibodies, chimeric antibodies, diabodies and polypeptides that contain at least a portion of an immunoglobulin that is sufficient to confer specific antigen binding to the polypeptide. The Fc domain includes portions of two heavy chains contributing to two or three classes of the antibody. The Fc domain may be produced by recombinant DNA techniques or by enzymatic (e.g. papain cleavage) or via chemical cleavage of intact antibodies.

The antibody may be an IgG, an IgM, an IgE, an IgA or an IgD molecule. In a preferred embodiment, the antibody molecule is an IgG, and more preferably is of the IgG1, IgG2, IgG3, or IgG4 subtype. The class and subclass of antibodies may be determined by any method known in the art, for example, by using antibodies that are specific for a particular class and subclass of antibody. Antibodies specific to $\alpha V\beta 3$ are available commercially and are described above. The class and subclass can be determined by ELISA and Western Blots, as well as other techniques. Alternatively, the class and subclass may be determined by sequencing all or a portion of the constant domains of the heavy and/or light chains of the antibodies, comparing their amino acid sequences to the known amino acid sequences of various class and subclasses of immunoglobulins, and determining the class and subclass of the antibodies.

Antibodies are a major class of biopharmaceuticals. Antibodies for therapeutic purposes are often produced from a cell line (e.g. CHO cells, the hamster line BHK21, the human PER.C6 cell line, COS, NIH 3T3, BHK, HEK, 293, L929, MEL, JEG-3, murine lymphoid cells (including NS0 and Sp2/0-Ag 14)), including hybridomas, and are usually a single clone of a specific antibody. Antibodies used for therapeutic purposes are classified as murine, chimeric, humanized or fully human antibodies and are produced by recombinant methods. A “murine antibody” is a full mouse antibody and has only limited use in humans due to its short half-life in circulation and its high immunogenicity. A “chimeric antibody” is a genetically engineered antibody, which contains both mouse and human sequences. The ratio is approximately 33% mouse contribution and 67 % human contribution. Usually the variable domains are murine and the constant region including the Fc fragment is derived from a human IgG.

A “humanized antibody” is a genetically engineered antibody, wherein the mouse content is reduced to about 5-10%. In such cases, the six CDRs of the heavy and light chains and a limited number of structural amino acids of the murine monoclonal antibody are grafted by recombinant technology to the CDR-depleted human IgG scaffold. A fully human antibody or human antibody describes antibodies, which are made in humanized mice resulting in antibodies that do not contain any mouse sequences, or made in vitro using phage libraries or ribosome display or alternatively are obtained from human donors. In certain embodiments, chimeric, humanized or primatized (CDR-grafted) antibodies, comprising portions derived from different species or fully human antibodies, are also encompassed by the present invention. The various portions of these antibodies can be joined together chemically by conventional techniques, or can be prepared as a contiguous protein using genetic engineering techniques. For example, nucleic acids encoding a chimeric or humanized chain can be expressed to produce a contiguous protein. See, e.g., Cabilly et al., U.S. Pat. No. 4,816,567; Cabilly et al., European Patent No. 0,125,023; Boss et al., U.S. Pat. No. 4,816,397; Boss et al., European Patent No. 0,120,694; Neuberger, M. S. et al., WO 86/01533; Neuberger, M. S. et al., European Patent No. 0,194,276 B1; Winter, U.S. Pat. No. 5,225,539; and Winter, European Patent No. 0,239,400 B1. See also, Newman, R. et al., *BioTechnology*, 10: 1455-1460 (1992), regarding primatized antibody. See, e.g., Ladner et al., U.S. Pat. No. 4,946,778; and Bird, R. E. et al., *Science*, 242: 423-426 (1988)), regarding single chain antibodies.

In addition, a mixture of antibodies, termed herein as an “antibody preparation”, can be used according to the methods of the present invention. Such antibody preparations include polyclonal and monoclonal mixtures of antibodies. A humanized antibody may comprise portions of immunoglobulins of different origin. For example, at least one portion can be of human origin. For example, the humanized antibody can comprise portions derived from an immunoglobulin of nonhuman origin with the requisite specificity, such as a mouse, and from immunoglobulin sequences of human origin (e.g., a chimeric immunoglobulin), joined together chemically by conventional techniques (e.g., synthetic) or prepared as a contiguous polypeptide using genetic engineering techniques (e.g., DNA encoding the protein portions of the chimeric antibody can be expressed to produce a contiguous polypeptide chain). Alternatively, a humanized antibody may be created in a transgenic or humanized animal expressing the human antibody genes (see Lonberg, N. "Transgenic Approaches to Human Monoclonal Antibodies." Handbook of Experimental Pharmacology 113 (1994): 49-101). Another example of a humanized antibody of the present invention is an immunoglobulin containing one or more immunoglobulin chains comprising a CDR of nonhuman origin (e.g., one or more CDRs derived from an antibody of nonhuman origin) and a framework region derived from a light and/or heavy chain of human origin (e.g., CDR-grafted antibodies with or without framework changes). Chimeric or CDR-grafted single chain antibodies are also encompassed by the term “humanized antibody”.

Methods of preparing immunoglobulins, immunizing with antigens, and polyclonal and monoclonal antibody production can be performed as described herein, or using other suitable techniques. A variety of methods have been described. See e.g., Kohler et al., Nature, 256: 495-497 (1975) and Eur. J. Immunol. 6: 511-519 (1976); Milstein et al., Nature 266: 550-552 (1977); Koprowski et al., U.S. Pat. No. 4,172,124; Harlow, E. and D. Lane, 1988, Antibodies: A Laboratory Manual, (Cold Spring Harbor Laboratory: Cold Spring Harbor, N.Y.); Current Protocols In Molecular Biology, Vol. 2 (Supplement 27, Summer '94), Ausubel, F. M. et al., Eds., (John Wiley & Sons: New York, N.Y.), Chapter 11, (1991; Rasmussen SK, Rasmussen LK, Weilguny D, Tolstrup AB. Biotechnol Lett. 2007 Feb 20.). Polyclonal antibodies which may be used in the methods of the invention are heterogeneous populations of antibody molecules derived from the sera of immunized animals (using $\alpha V\beta 3$ -specific peptides or recombinant proteins as an immunogen). For preparation of Monoclonal antibodies directed to $\alpha V\beta 3$, a hybridoma can be produced by fusing a suitable immortal cell line (e.g., a myeloma cell line such as SP2/0) with antibody producing cells. The antibody producing cell, preferably

those of the spleen or lymph nodes, are obtained from animals immunized with the antigen of interest (α V β 3-specific peptide or recombinant protein). Hybridomas can be isolated using selective culture conditions, and cloned by limiting dilution. Cells that produce antibodies with the desired specificity can be selected by a suitable assay (e.g., ELISA). Antibodies can be purified from the plasma of human donors. This is the current approach for IVIg where immunoglobulins are isolated from normal plasma pooled from a large number of donors (see <http://www.fda.gov/cber/gdlns/igivimmuno.htm> and Haeney Clin Exp Immunol. 1994 July; 97(Suppl 1): 11–15.) Other suitable methods for producing or isolating antibodies of the requisite specificity can be used, including, for example, methods which select recombinant antibodies from a library, or which rely upon immunization of transgenic animals (e.g., mice) capable of producing a full repertoire of human antibodies. See e.g., Jakobovits et al., Proc. Natl. Acad. Sci. USA, 90: 2551-2555 (1993); Jakobovits et al., Nature, 362: 255-258 (1993); Lonberg et al., U.S. Pat. No. 5,545,806; Surani et al., U.S. Pat. No. 5,545,807.

An antibody may have one or more binding sites. If there is more than one binding site, the binding sites may be identical to one another or may be different. For instance, a naturally occurring immunoglobulin has two identical binding sites, a single-chain antibody or Fab fragment has one binding site, while a "bispecific" or "bifunctional" antibody has two different binding sites. An individual antibody's ability to internalize, deliver a payload, and kill a target cell can vary greatly depending on the affinity and the particular target epitope that is engaged by the antibody. For a given target in this case IL1RAPL-1 a panel of antibodies should be developed (will cover a range of binding affinities and epitopes) for ADC conjugation. The term "human antibody" includes all antibodies that have one or more variable and constant regions derived from human immunoglobulin sequences. In one embodiment, all of the variable and constant domains are derived from human immunoglobulin sequences (a fully human antibody). The term "chimeric antibody" refers to an antibody that contains one or more regions from one antibody and one or more regions from one or more other different antibodies. In one embodiment, one or more of the CDRs are derived from a specific human antibody. In a more preferred embodiment, all of the CDRs are derived from a human antibody. In another preferred embodiment, the CDRs from more than one human antibody are mixed and matched in a chimeric antibody. For instance, a chimeric antibody may comprise a CDR1 from the light chain of a first human antibody combined with CDR2 and CDR3 from the light chain of a second human antibody, and the CDRs from the heavy chain may be derived from a third antibody. Further, the framework regions may be derived from one of the same

antibodies, from one or more different antibodies, such as a human antibody, or from a humanized antibody. (chimeric is not listed on page 4 –see antibody and fragments specific for the target protein).

5 Experimental

Cell culture Conditions

Primary derived Human Aortic Endothelial Cells were purchased from Promocell GmbH (Heidelberg Germany). The cells were routinely grown in Cell+ T75 tissue culture flasks containing Promocell Endothelial Cell Growth Media MV supplemented with 5% foetal calf serum, 0.4% endothelial cell growth supplement/bovine hypothalamic extract, heparin (90 mg/mL), hydrocortisone (1 mg/mL), epidermal growth factor (10 ng/mL), and antibiotics (100 U/mL penicillin, 100 mg/mL streptomycin) Cells were grown in a humidified atmosphere of 5% CO₂/95% air at 37°C. For all experiments cells between passages 6 and 12 were used. HAoECs were seeded at 0.4×10^6 into 6 well plates and grown to confluency. The HAoECs were sheared by applying 10dynes/cm² of shear stress for 24hrs. After shearing cells were either experimented upon in the 6 well plate or harvested for seeding into adhesion assays, proliferation and permeability assays.

20 *Bacterial culture conditions*

Bacterial cultures of S. aureus and E.coli were grown to stationary phase at 37°C in brain heart infusion broth. *L. lactis* was grown to stationary phase at 37°C in M17 Agar supplemented with glucose to a final concentration of 0.5%. Mutant strains *L. lactis* +ClfA was grown in the presence of erythromycin to a final concentration of 5ug/ml and *L. lactis* +ClfA PY was grown in the presence of chloramphenicol to a final concentration of 10ug/ml. Bacteria were harvested and washed by centrifuging at 2600 x g for 7 minutes and re-suspending in PBS pH 7.4 and adjusted to OD₁ at 600nm. For experiments utilising fluorescent staining Tris Buffered Saline (TBS) pH 7.4 (50 mM Tris, 150mM NaCl) was used in place of PBS to avoid any incompatibility with phosphate groups in the buffer.

30

Immunohistochemistry

Glass cover slips, (type 1, 24 x 24 mm 0.17mm thick borosilicate glass) were attached to the base of a 6 well tissue culture sealing the lower edges with a PAP pen. HAoECs were seeded into the well at 600,000 cells per well incubating for 24 hrs to assure attachment to the glass

cover slips. The media in the well was replaced and the cells exposed to a shear force of 10 dyn/cm² for 24 hrs. After shearing the media was removed, the cover slip removed from the well and the cells washed with 37°C PBS. The cells were fixed with 3.7% formaldehyde in PBS for 20 minutes on ice, washed and permeabilised with 0.2% triton 100X in PBS for 5 minutes at room temperature. Liquid was removed and the cells were washed with 2 ml of PBS three times. Cells were blocked with 1.5 ml per well 5% BSA in PBS for 30 minutes at room temperature and washed three times with PBS. Monoclonal anti ZO-1 antibody was added to the cells at a 1:100 dilution in 400 µl of 5% BSA and incubated overnight at 4°C. After the cells were washed and secondary antibody Alexaflour 488, Rabbit anti goat was added at a concentration of 1:1000 in 1 ml of BSA incubating on the cells for 1 hr at room temperature in the dark. After secondary antibody staining the cells were washed three times in 1 ml of PBS. One drop of ProLong® Diamond Antifade Mountant with DAPI was added to a glass microscope slide and the cover slip with cells was mounted to it. Images were acquired using an inverted fluorescence microscope (Zeiss AxioObserverZ1) equipped with plan-apochromat 63x/1.40 oil immersion objective (Ex/Em 488nm/>505nm for ZO-1 and 350/> 400nm for DAPI). Static cells for comparison to sheared were prepared in the same manner but omitting the shearing step overnight.

Binding Assay

Sheared HAoECs were seeded into wells of a 96 well tissue culture plate at a density of 2.5×10^4 cells per well in a volume of 100µl. Experiments were carried out either in the presence or absence of TNFα at 10 ng/ml. The HAoECs were incubated at 37°C 5% CO₂ for 4 hours to facilitate attachment and cell-cell contact on the plate. Following the 4 hr incubation the media was removed and 100µl of human platelet poor plasma (PPP), 4 mg/ml fibrinogen or 1mg/ml IgG was added to each well and incubated for 1hr at 37°C 5% CO₂. The wells were washed with PBS and the wells were blocked with 100 µl of 1% pre well for 1 hr at 37°C. Finally the wells were washed with 100 µl of TBS and 100 µl of SYBR green II stained bacteria was added per well at a MOI of 400. The cells were incubated for a further 1 hr at 37°C 5% CO₂ and then read on a fluorescent plate reader (1420 Victor V3, Perkin Elmer, Dublin, Ireland) at 485/535 nm. The bacteria were then removed gently by pipette and the plate washed with 100 µl TBS/well. The plate was then read again at 485/535 nm. Adhered bacteria were calculated as a percent remaining from the initial reading multiplied by the number of bacteria added. Depletion of plasma was carried out by re suspending a pellet of 1 ml of OD1 *L. lactis* +ClfA in 1 ml of human hirudinised plasma. This was left on a rotator at 37°C for 1 hr, centrifuged at

3200 x g for 5 minutes and the supernatant removed. The plasma now deficient in the plasma proteins bound to by ClfA was used in the bacterial adhesion assay. Blocking of endothelial cells with c(RGDfV) was carried out by an additional step after the 4 hour incubation with TNF α and before the addition of fibrinogen. Removing the TNF α containing media 100 μ l of new media containing 0.05 μ M C(RGDfV) was added to the endothelial cells and incubated for 1 hour at 37°C. This experiment was repeated using *E. coli*.

Dot blot

Overnight growths of wild type *S. aureus* Newman Wild, mutants, *L. lactis* mock transfected and mutant strains adjusted to OD₁ at 600 nm in PBS and lysed using RIPA buffer. A spot of the lysate was placed on a nitrocellulose membrane allowed to dry at room temperature. The membrane was blocked with 5 % w/v skimmed milk proteins. Membranes were probed with anti ClfA or anti SpA antibodies followed by HRP conjugated secondary antibodies. Secondary antibody was detected by the addition of enhanced chemiluminescence solution to the membrane for 5 minutes before transferring the membrane to a radiographic cassette and exposing x-ray film to the membranes in a dark room.

Flow Cytometry

Sheared HAoECs in a 6 well plate were exposed to 1 ng of TNF α per 25,000 endothelial cells or fresh media and were incubated for 4 hrs at 37°C. The TNF α containing media was removed and 1 ml of 4mg/ml Fg in media at 37°C for 1 hr. Cells were detached by trypsinization and pelleted. The cell pellet was washed in ice cold (4°C) PBS before being probed with anti α v β 3 antibody LM609 for 15 minutes, washed and probed with a 535 anti-mouse secondary. Cells were analysed on a flow cytometer (BD FACSCanto™ II Flow Cytometer).

Proliferation assay

Sheared HAoECs were seeded into a six well plate at 150,000 cells per well in 1.6ml media containing 10 ng/ml of TNF α . The cells were incubated for 4 hrs at 37°C in a 5% CO₂. The media was replaced by 1.6ml of either fresh media or media containing 0.05 μ M cilengitide and incubated for 1hr. Following this media was removed and 1 ml of 4 mg/ml fibrinogen was added per well incubating for a further hour. The media was removed and the well washed with antibiotic free media. To each well 1.6ml of antibiotic free media was added containing *S. aureus* Newman or *S. aureus* Δ ClfA for a MOI of 400. The cells were incubated at 37°C in for 24 hrs. Following incubation the media was removed from the cells and they were washed 4

times with warm PBS. The cells were detached from the 6 well plate by trypsinization counted on a haemocytometer.

Apoptosis assay

- 5 Sheared HAoECs in a 6 well plate were exposed to 1 ng of TNF α per 25,000 endothelial cells and were incubated for 4 hrs at 37°C. The TNF α containing media was removed and 1 ml of 4mg/ml Fg in media at 37°C for 1 hr. Media was removed and replaced with 1 ml of antibiotic free media containing *S. aureus* Newman WT or Newman Δ ClfA to a MOI of 400 in a final volume per well of 2 ml. The cells were incubated for 24 hrs at 37°C. Following incubation the
10 media was removed and the wells washed 3 times with warm PBS. Cells were detached by trypsinization and pelleted. The cell pellet was washed in ice cold (4°C) PBS before being stained with a TACS™ Annexin V Apoptosis Kit. The cells were analysed on a flow cytometer (BD FACSCanto™ II Flow Cytometer). The experiment was repeated to test α v β 3 blocking by cilengitide at 0.05 μ M for 1 hr between the TNF α exposure and the addition of 4 mg/ml
15 fibrinogen for 1 hr. This experiment was repeated using *E. coli* and *E. coli* Δ ompA instead of *S. aureus* Newman WT or Newman Δ ClfA.

Permeability

- Endothelial barrier permeability was assessed using a transwell apparatus with the slight
20 modifications. Sheared HAoECs were trypsinized and seeded into hanging inserts, were placed in a 6 well plate. To the lower (abluminal) chamber of the plate 4 ml of cell media was added and 2 ml of media containing 200,000 cells/ml was added to the top (luminal) chamber. The wells plates were incubated at 37°C in a 5% CO₂ and humidified atmosphere overnight to form a confluent monolayer. Media in the abluminal chamber was changed to antibiotic free media
25 while simultaneously the media in the luminal chamber was removed and washed with antibiotic free media. Cells were infected with *S. aureus* Newman WT and *S. aureus* Δ ClfA in 2 ml of antibiotic free media to infect the cells at a MOI of 400 for 3 hrs at 37°C. FITC dextran (40 kDa) was added to the top chamber for a final concentration of 250 μ g/ml in 2 ml. Media samples from the abluminal chamber were taken 24hrs after infection measured on a
30 plate reader at fluorescence Ex/Em 485/535 nm. The experiment was repeated to test α V β 3 blocking by cilengitide at 0.05 μ M for 1 hr between the TNF α exposure and the addition of 4 mg/ml fibrinogen in place of plasma for 1 hr. This experiment was repeated using *E. coli* and *E. coli* Δ ompA instead of *S. aureus* Newman WT or Newman Δ ClfA.

MTT cytotoxicity assay

Cell metabolic activity was measured using a MTT ((3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) assay kit. Sheared HAoECs were seeded into a clear 96 well microtitre plate at a density of 2.5×10^4 cells/well in 100 μ l in media containing 10 ng/ml TNF α .

5 The cells were incubated for 4 hrs at 37°C. Media was removed from the wells after 4 hrs and replaced with 100 μ l of fresh cell media, cell media containing a vehicle or cell media containing 0.05 μ M cilengitide. The plate was incubated for a further one hour before the media was changed for 100 μ l of fresh cell media with 10 μ l of 12 mM MTT stock and the plate incubated at 37°C for 4 hrs. All but 25 μ l of liquid was removed from each well and 10 μ l of
10 DMSO was added per well. The plate was incubated for 10 minutes at 37°C before being read on a plate reader for absorbance at 570 nm.

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Claims

1. A functional $\alpha V\beta 3$ antagonist for use in the treatment or prevention of sepsis in a patient, in which the functional $\alpha V\beta 3$ antagonist is delivered to the patient intravenously.
5
2. The functional $\alpha V\beta 3$ antagonist for use according to Claim 1 in which the functional $\alpha V\beta 3$ antagonist is a low molecular weight antagonist.
3. The functional $\alpha V\beta 3$ antagonist for use according to Claim 2 in which the functional $\alpha V\beta 3$ antagonist is cilengitide or a functional variant thereof.
10
4. The functional $\alpha V\beta 3$ antagonist for use according to Claim 2 in which the functional $\alpha V\beta 3$ antagonist is cilengitide.
5. The functional $\alpha V\beta 3$ antagonist for use according to any preceding Claim, for early prevention or inhibition of the development of sepsis in a patient having or suspected of having a bacterial infection of the blood.
15
6. The functional $\alpha V\beta 3$ antagonist for use according to any of Claims 1 to 4, for early prevention or inhibition of the development of severe sepsis or septic shock in a patient having or suspected of having sepsis.
20
7. The functional $\alpha V\beta 3$ antagonist for use according to any preceding Claim, for treatment of severe sepsis or septic shock in a patient.
25
8. The functional $\alpha V\beta 3$ antagonist for use according to any preceding Claim in which the patient is also treated with an intervention selected from: intravenous antibiotics; intravenous fluids; and organ-specific intervention.
9. A pharmaceutical composition formulated for intravenous delivery to a patient and comprising a therapeutically effective amount of cilengitide and a therapeutically effective amount of an antibiotic.
30

10. A pharmaceutical composition according to Claim 9 in which the antibiotic is selected from a broad spectrum antibiotic, a gram-negative specific antibiotic, and a gram-positive specific antibiotic.

Figure 1.

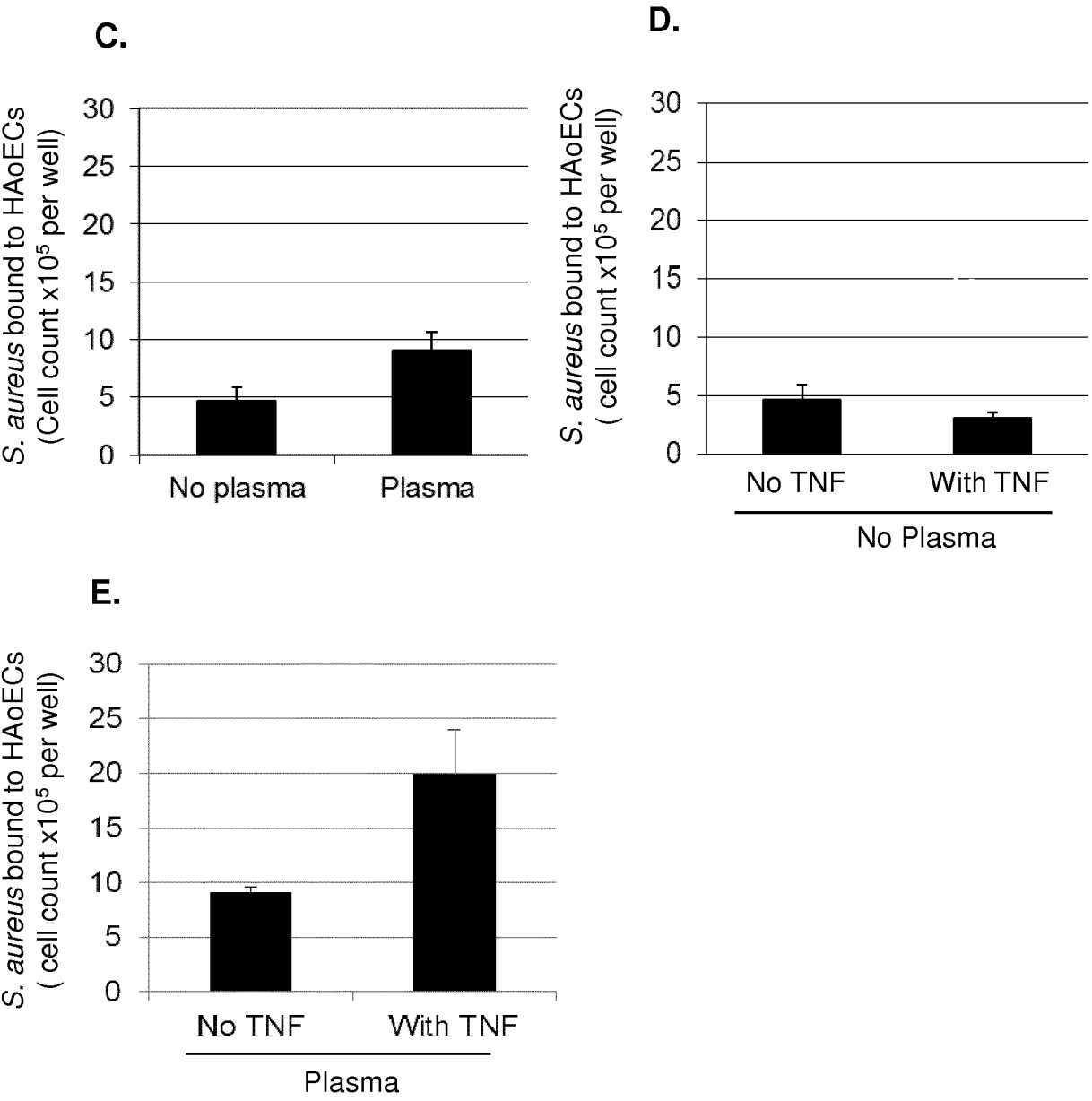
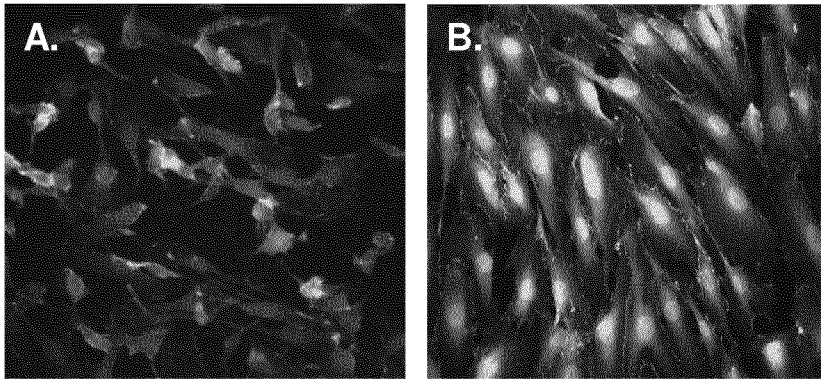


Figure 2.

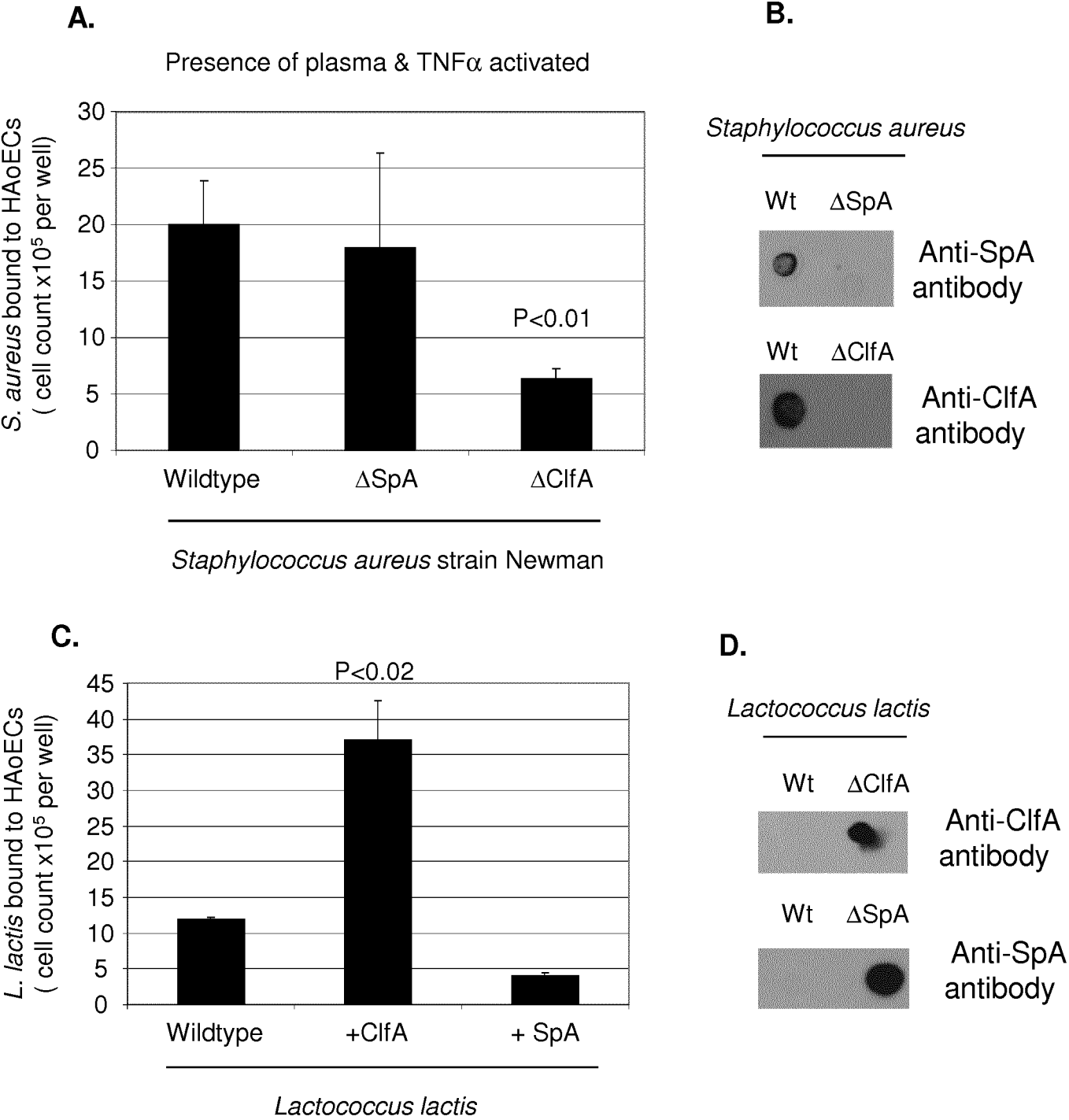


Figure 3.

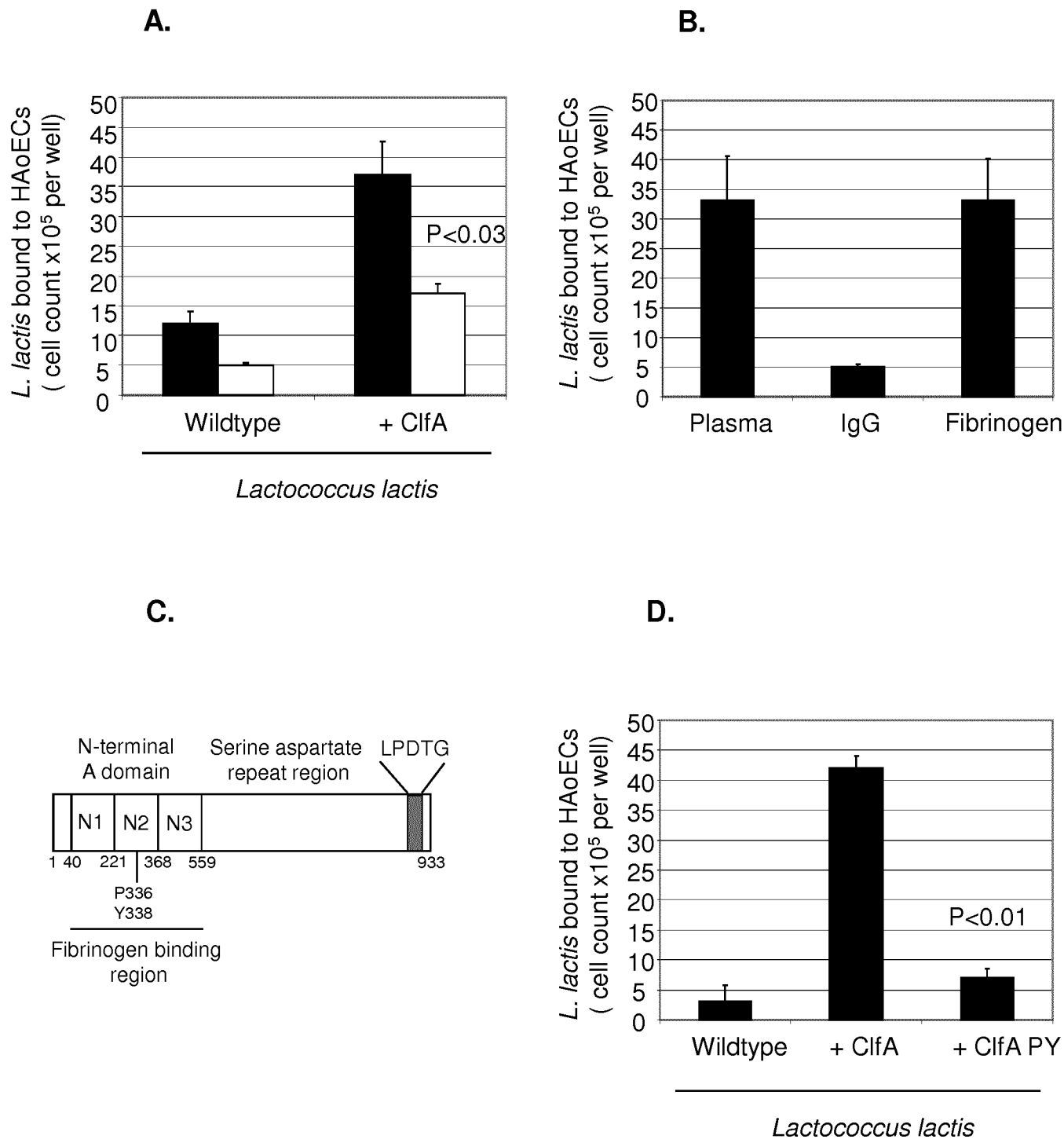


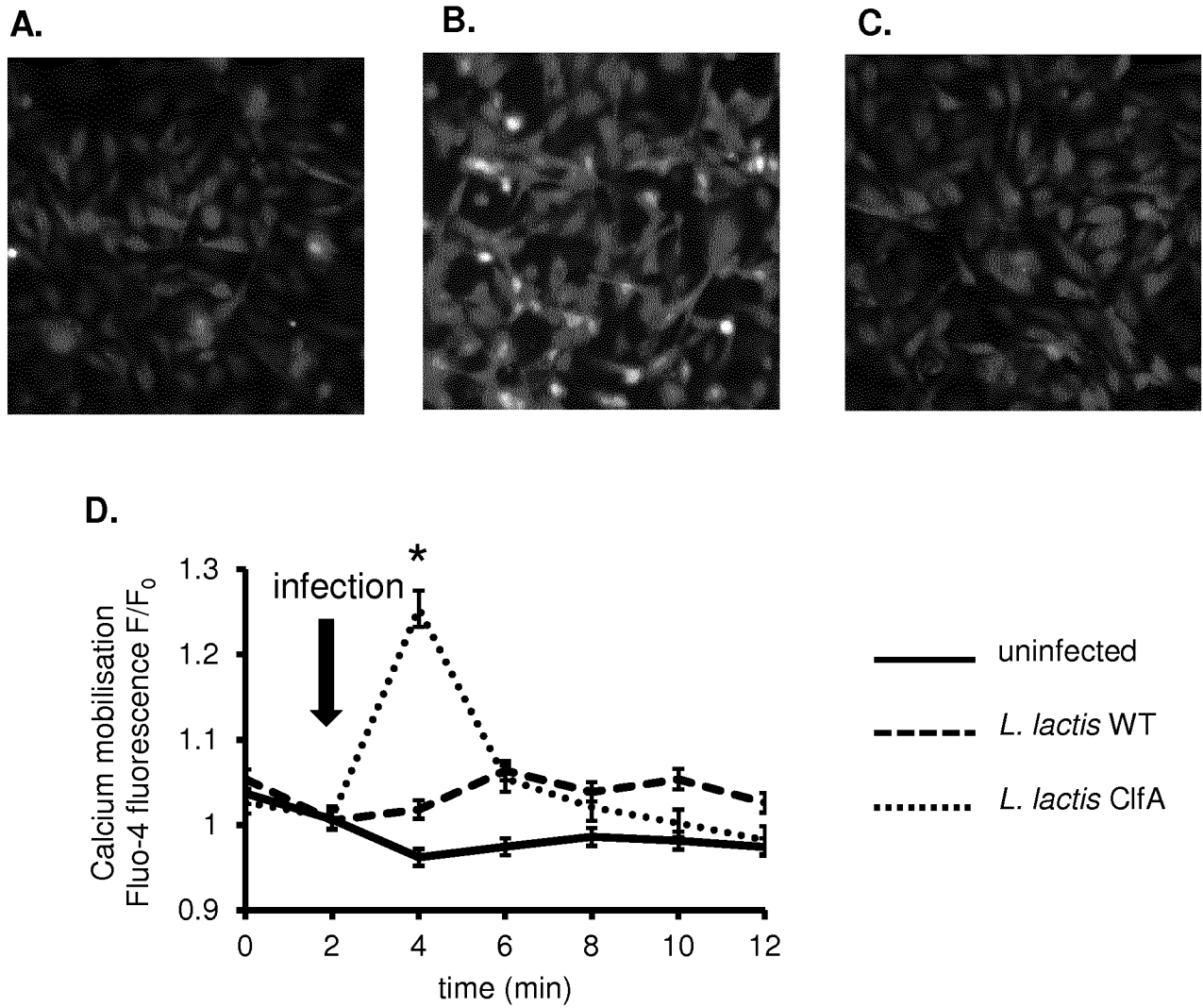
Figure 4.

Figure 5.

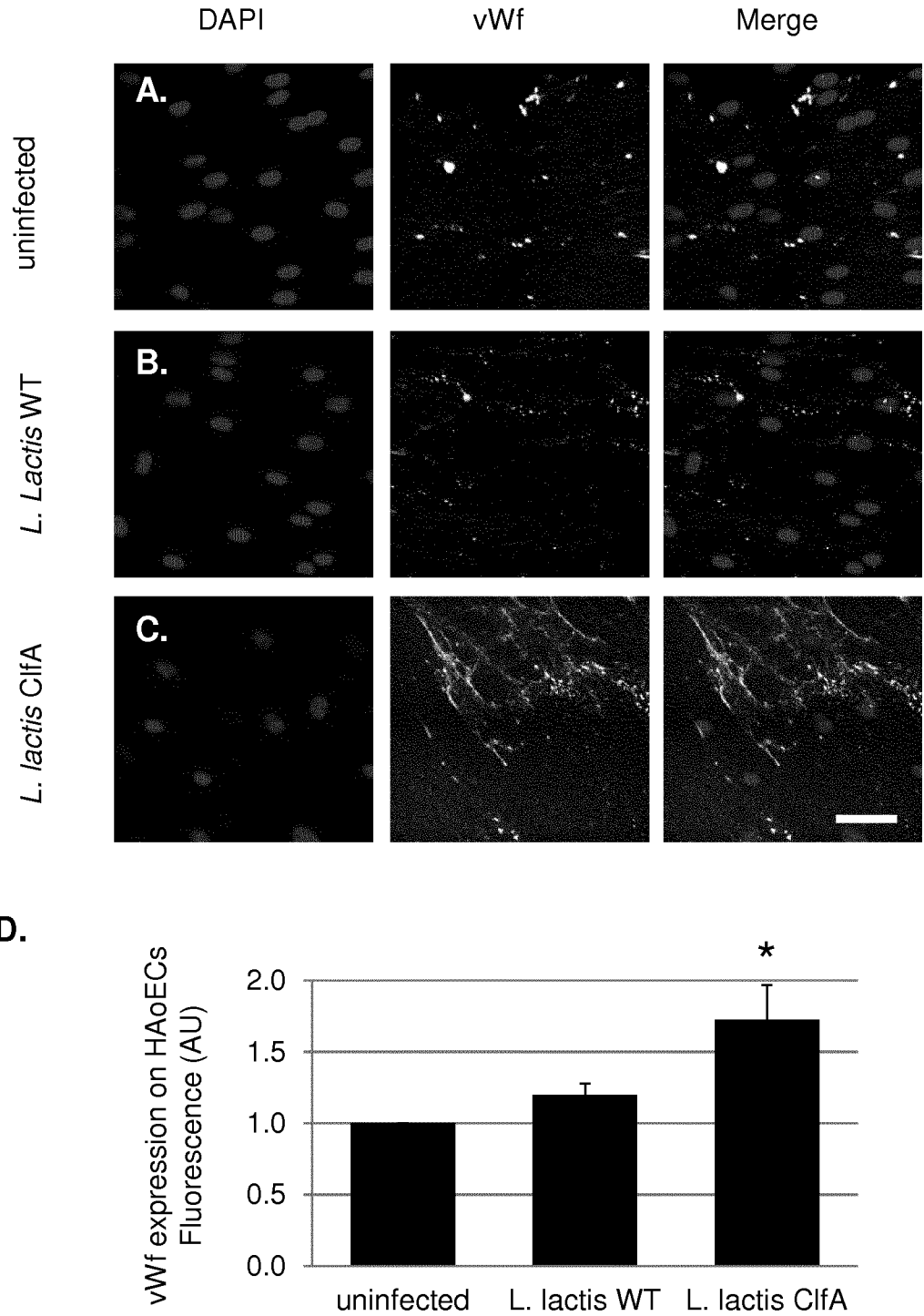


Figure 6.**A.**

Condition	LM609-PE binding (fl units)	% increase	P-value
Resting (No TNF α)	25 $\pm$ 3	-	-
Activated (With TNF α)	33 $\pm$ 2	31 $\pm$ X %	<0.05

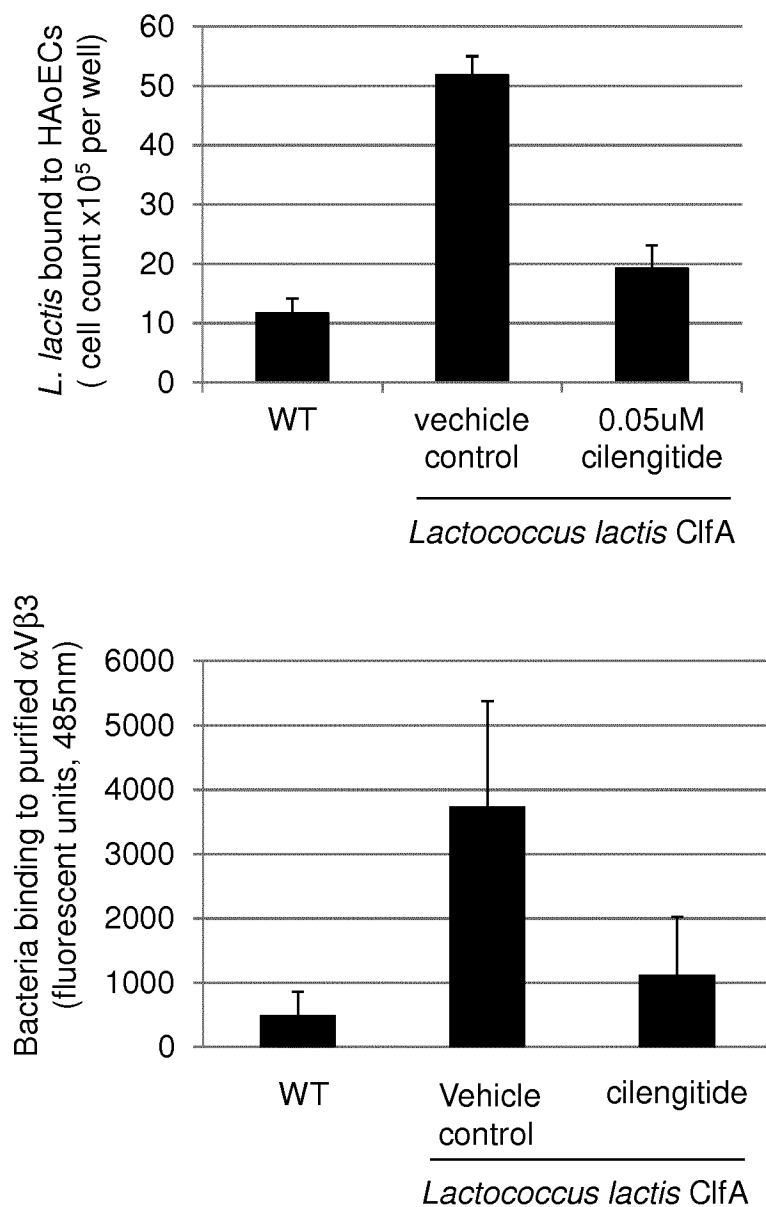
B.

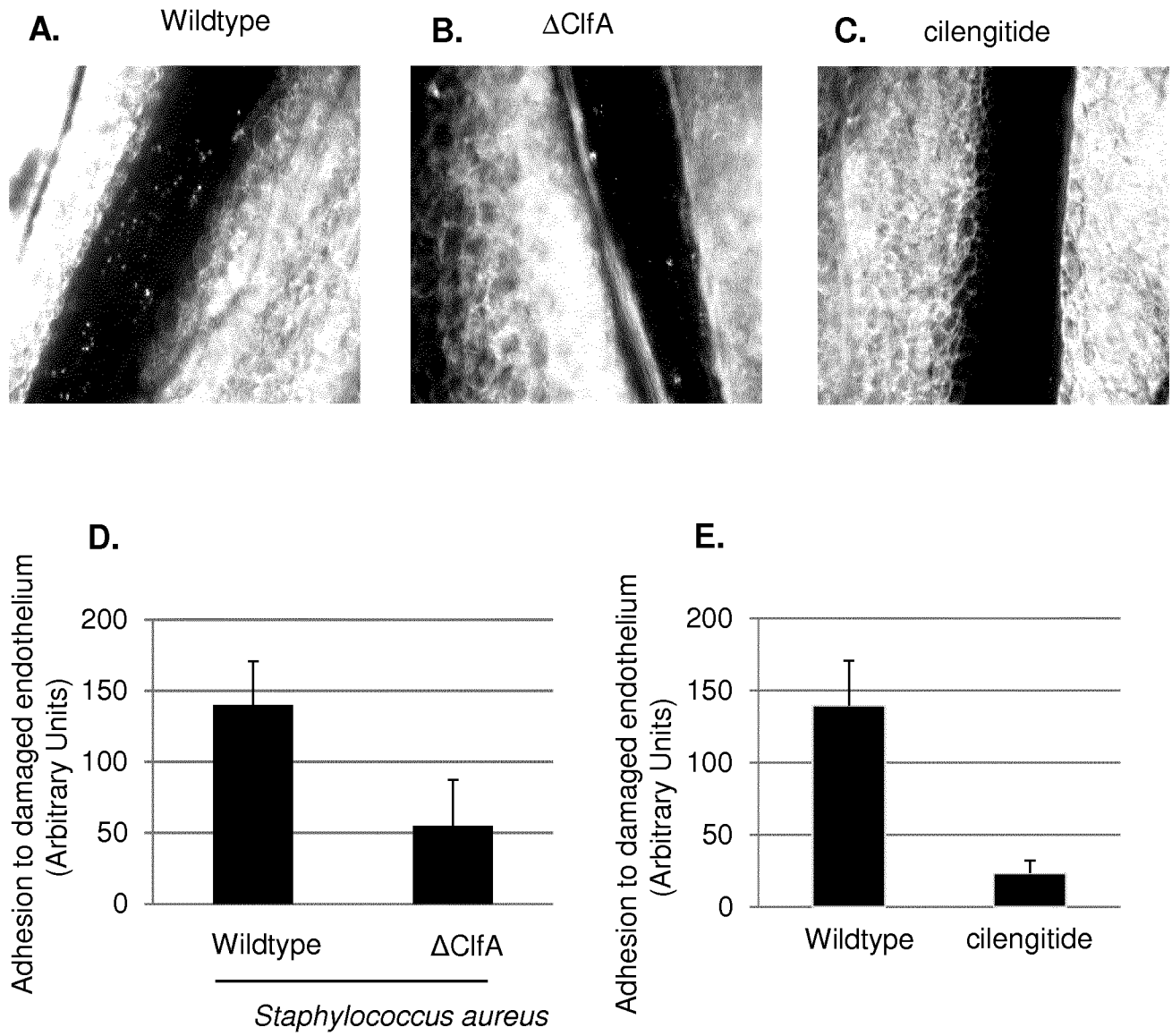
Figure 7.

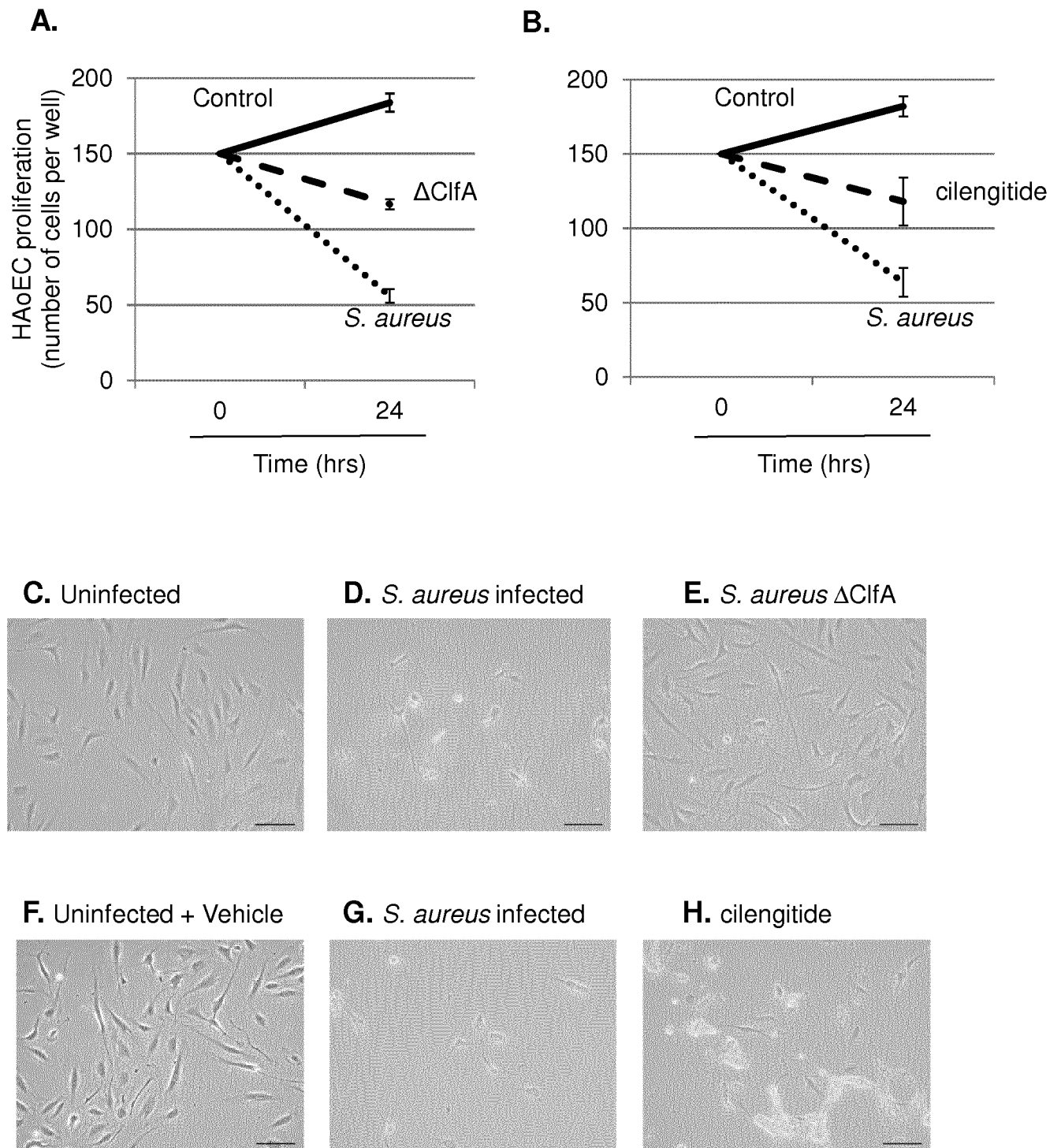
Figure 8.

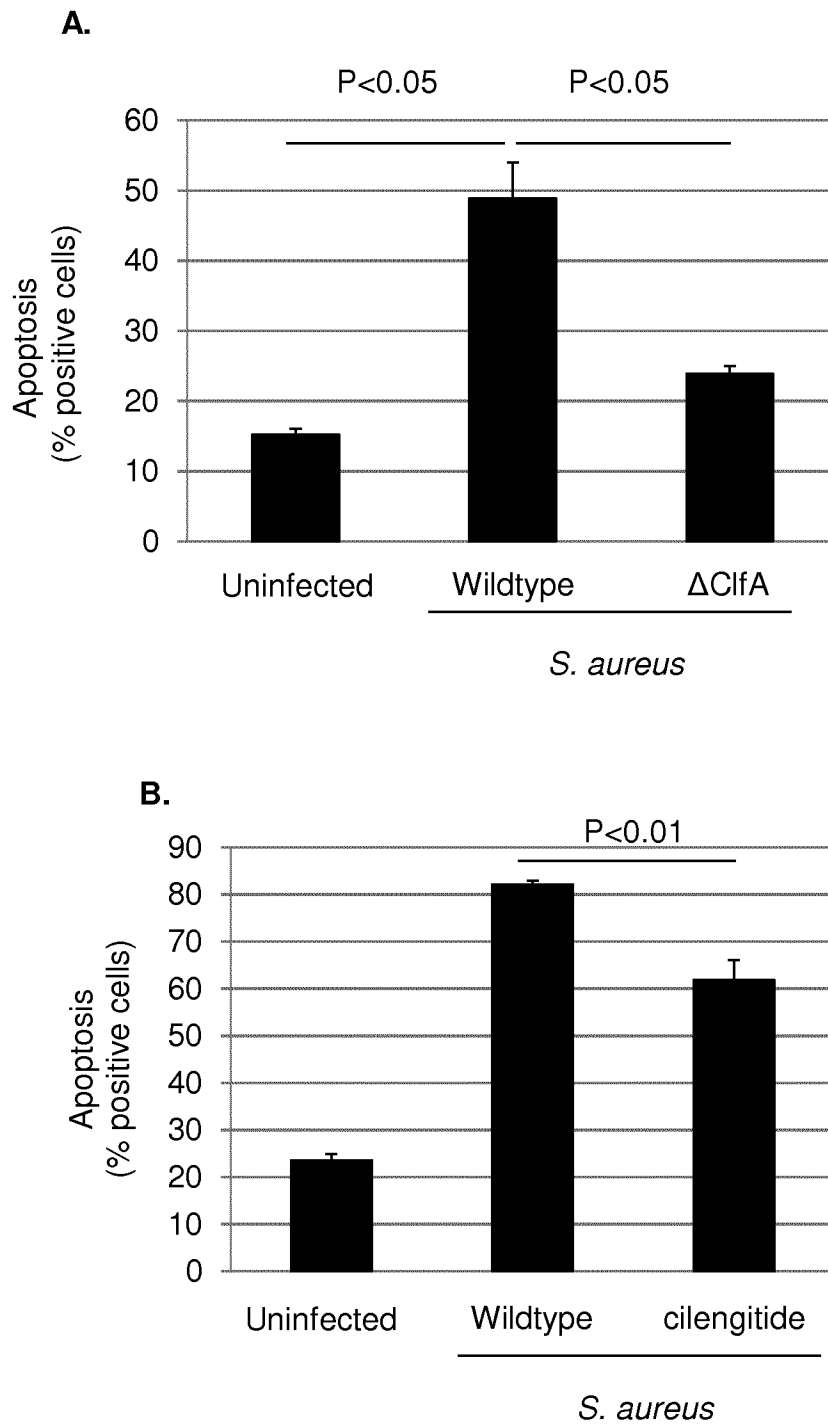
Figure 9.

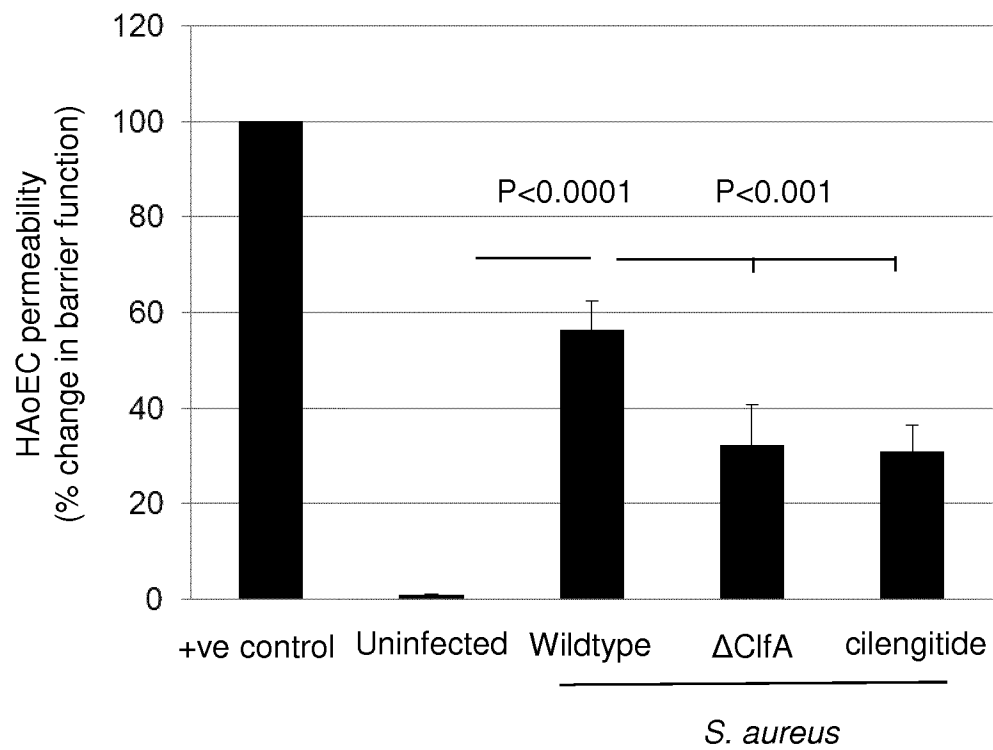
Figure 10.

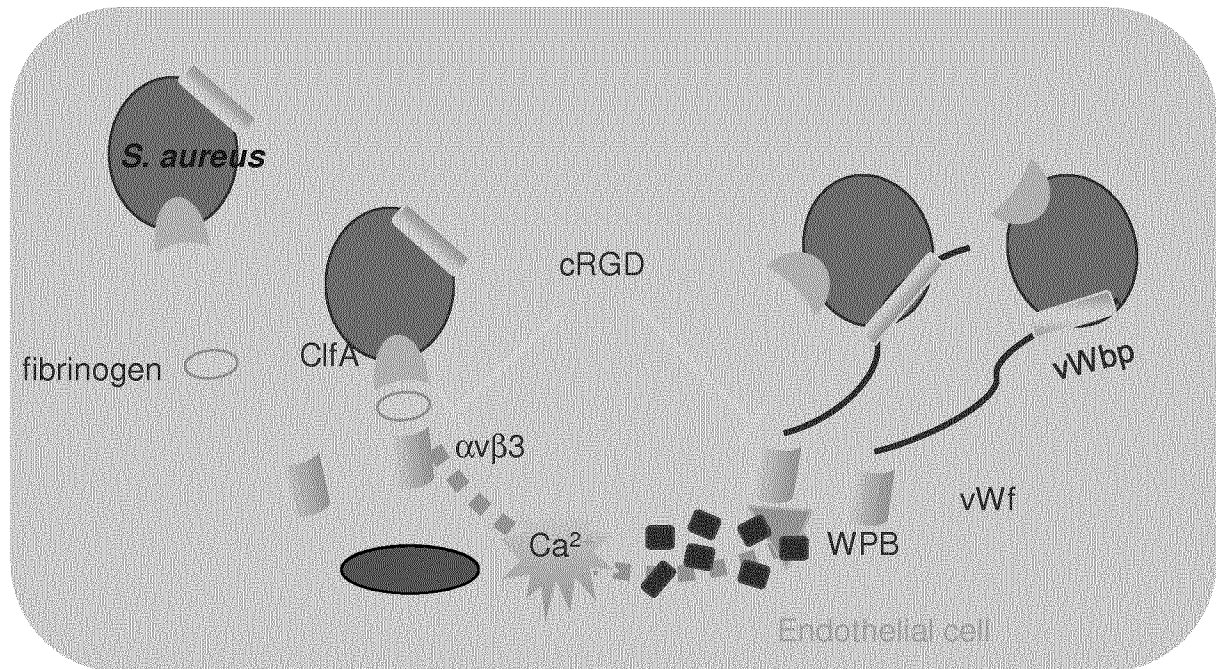
Figure 11.

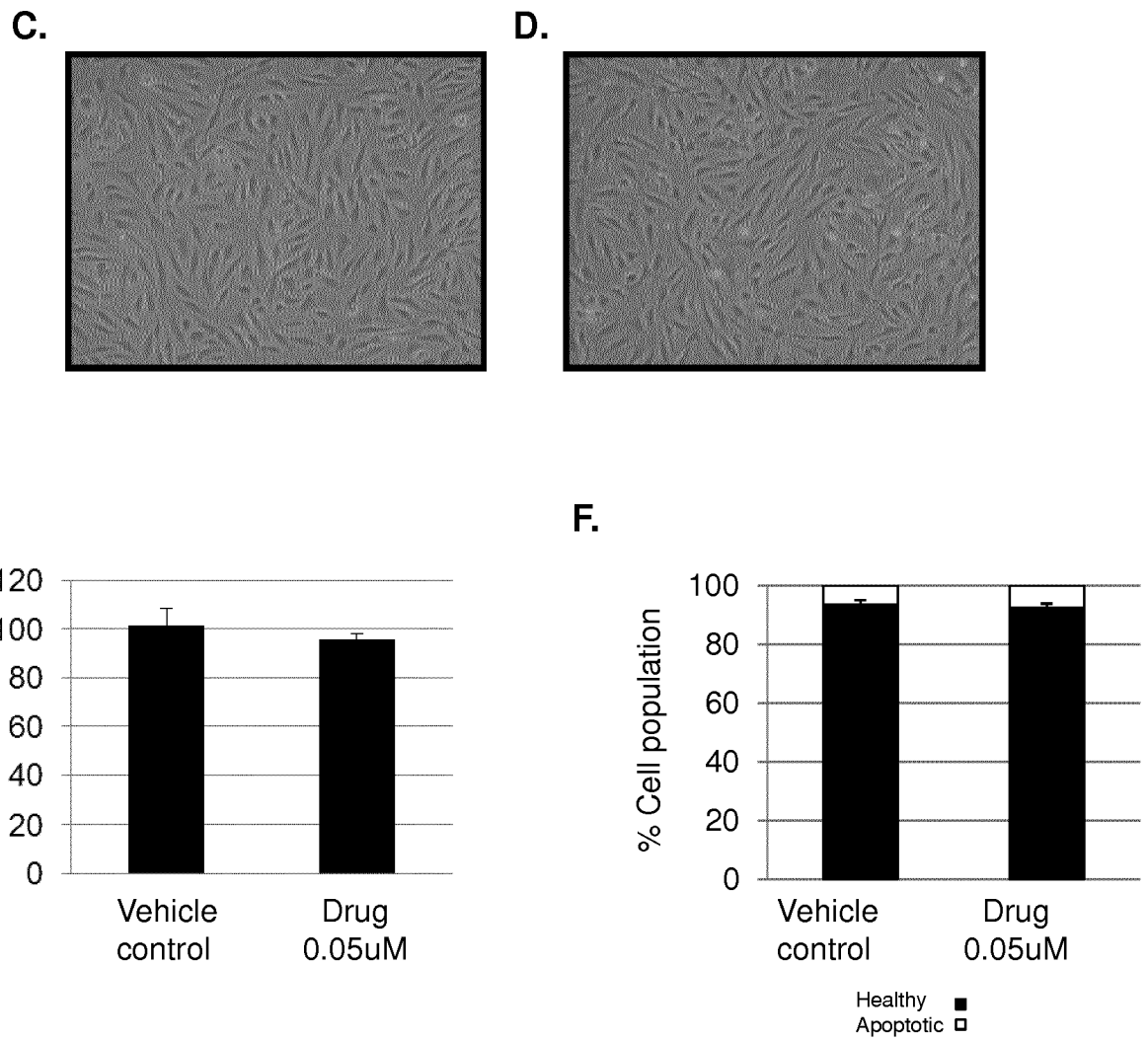
Figure 12

Figure 13.

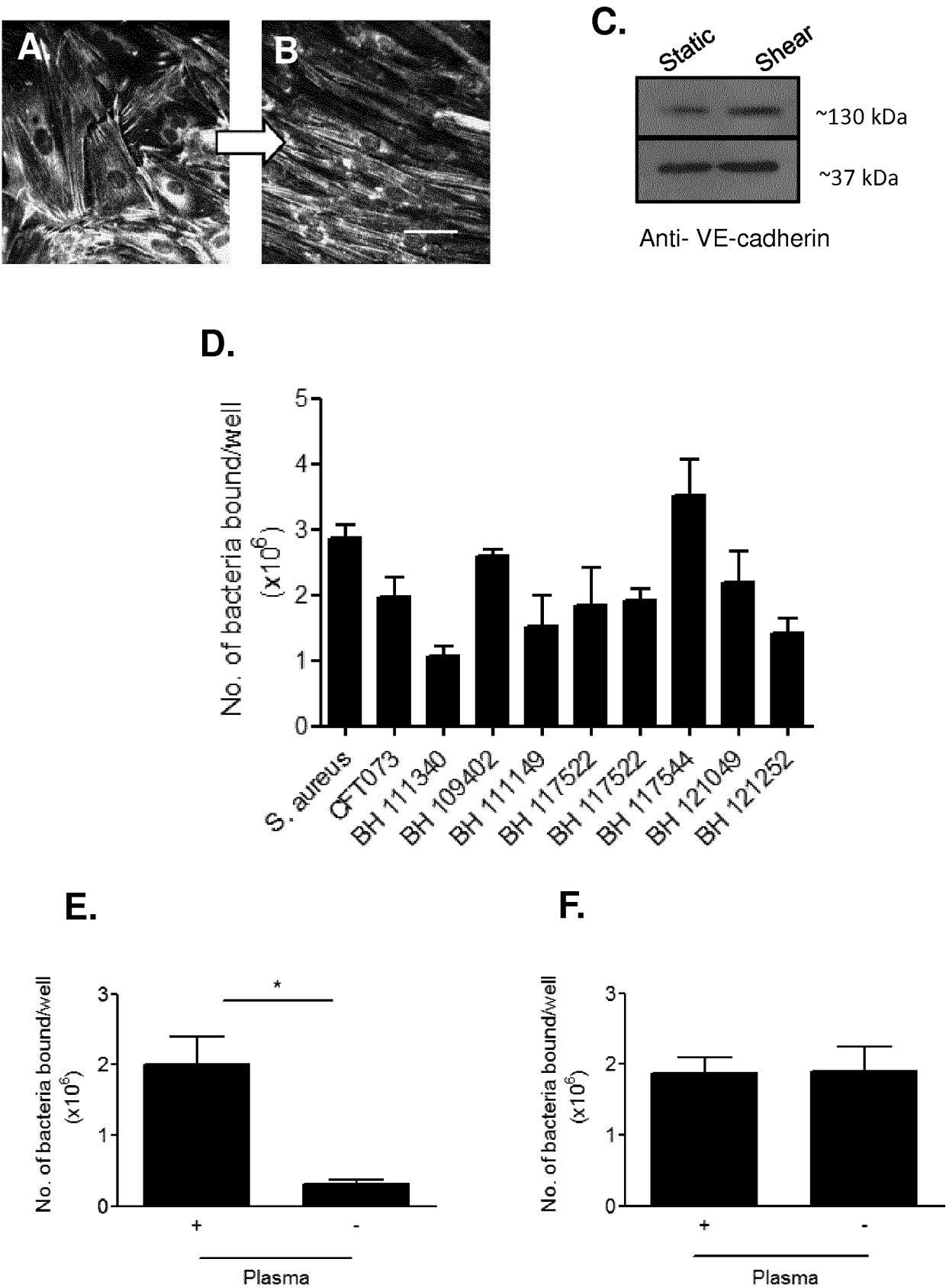


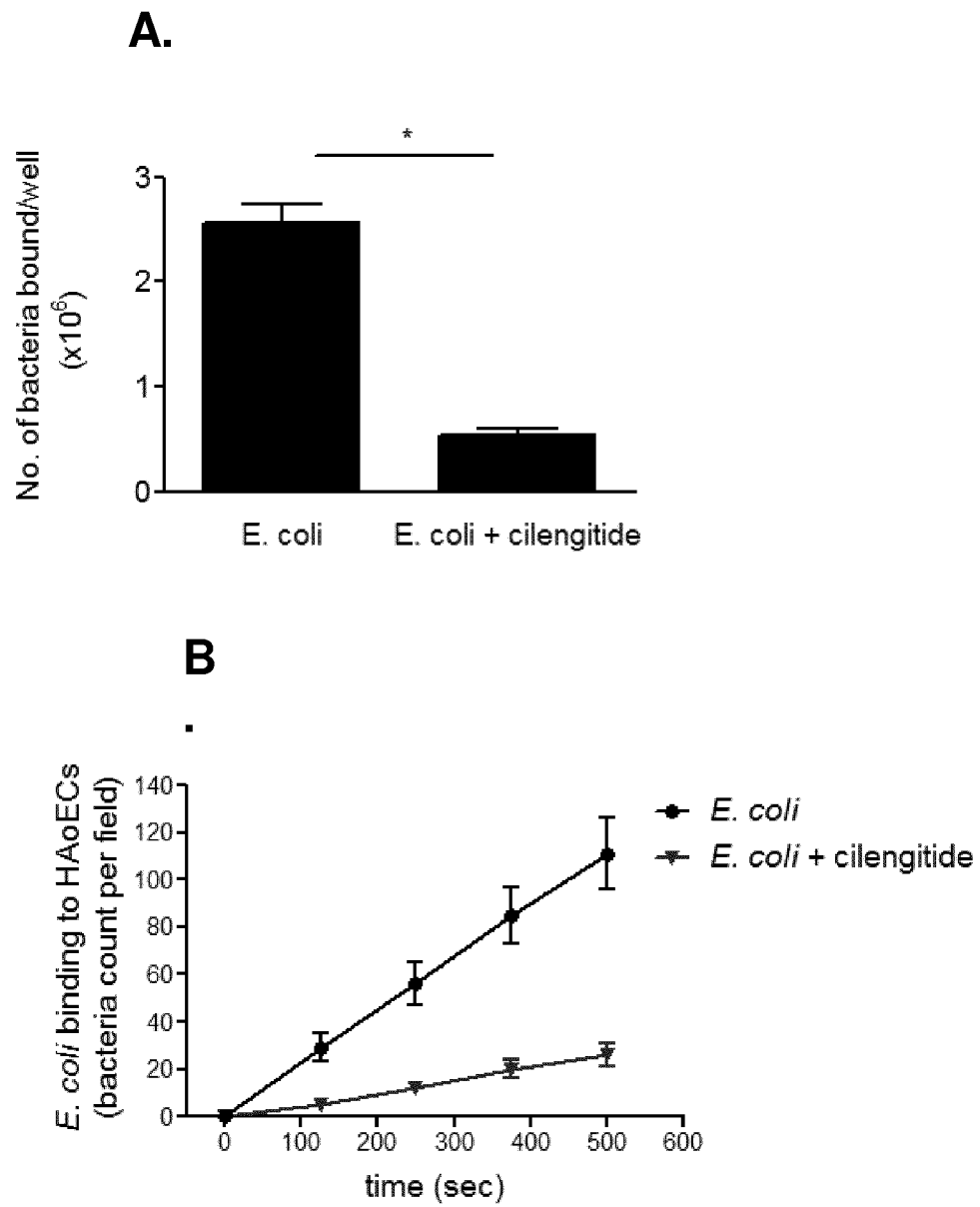
Figure 14.

Figure 15.

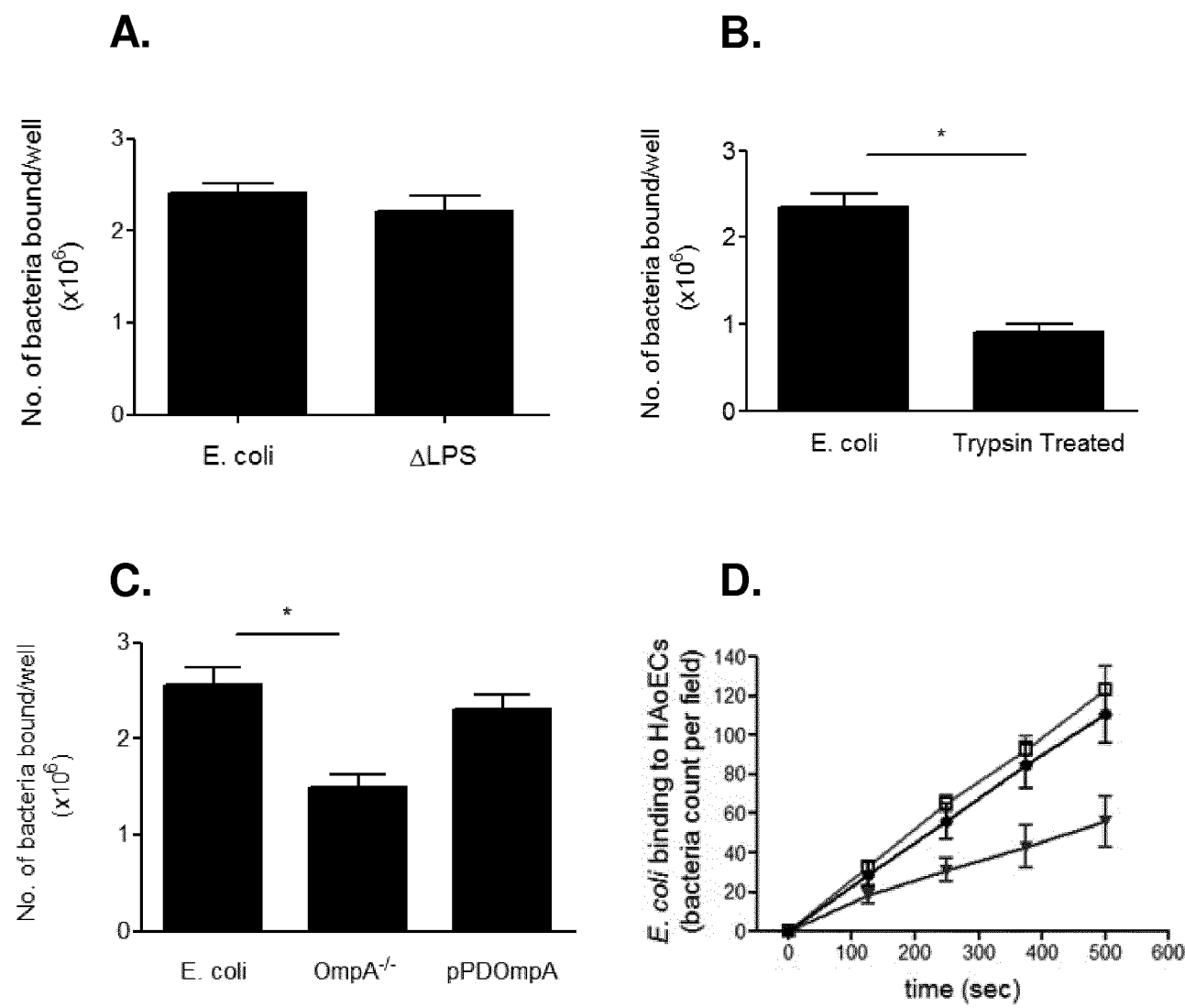


Figure 15E.

Protein	Function	Accession number
Flagellar M-ring protein	SEK <u>R</u> <u>G</u> DSL <u>N</u>	WP 000994423.1
Flagellar assembly protein fliH	WRL <u>R</u> <u>G</u> DPTL	AAN80816.1
Colicin I receptor	HRD <u>R</u> <u>G</u> DTYN	AAN81146.1
Outer membrane heme receptor	SRD <u>R</u> <u>G</u> DLRQ	AAN82744.1
Maltoporin	SF <u>G</u> <u>R</u> <u>G</u> DSDE	WP_000973666.1
Outer membrane protein A	MPYK <u>G</u> DNIN	AAN79561.1

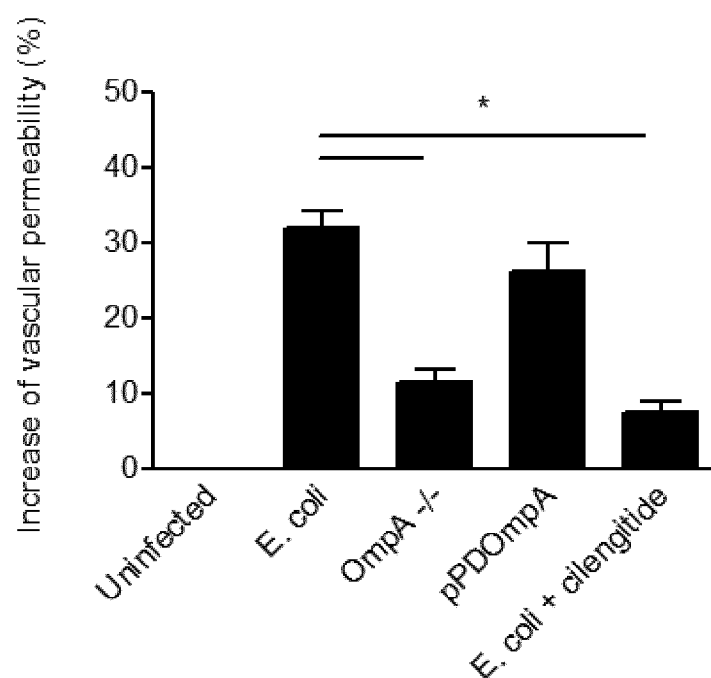
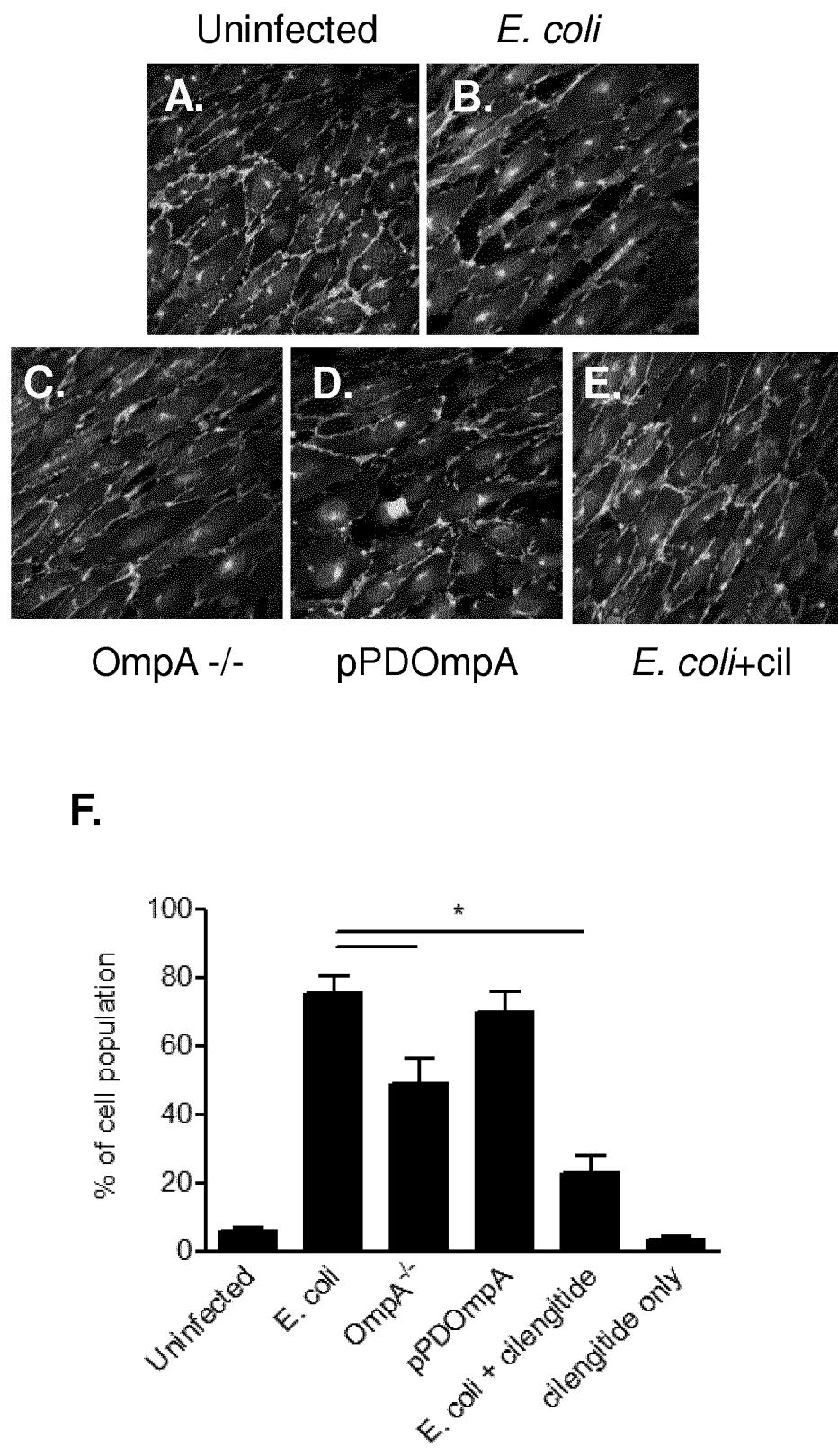
Figure 16.

Figure 17.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/053647

A. CLASSIFICATION OF SUBJECT MATTER

INV. A61K38/12 A61P31/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61K A61P

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 practicable, search terms used)

EPO-Internal, BIOSIS, EMBASE, FSTA, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	PRANITA P. SARANGI ET AL: "Role of [beta]1 Integrin in Tissue Homing of Neutrophils During Sepsis", SHOCK, vol. 38, no. 3, 1 August 2012 (2012-08-01), pages 281-287, XP055289740, US ISSN: 1073-2322, DOI: 10.1097/SHK.0b013e31826136f8 abstract page 3, paragraph 1; figure 1 ----- -/--	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search

4 May 2017

Date of mailing of the international search report

15/05/2017

Name and mailing address of the ISA/

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Authorized officer

Habadanck, Robert

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2017/053647

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	C.-C. HSU ET AL: "Improvements in endotoxemic syndromes using a disintegrin, rhodostomin, through integrin [alpha]v[beta]3-dependent pathway", JOURNAL OF THROMBOSIS AND HAEMOSTASIS, vol. 9, no. 3, 1 March 2011 (2011-03-01), pages 593-602, XP055289326, GB ISSN: 1538-7933, DOI: 10.1111/j.1538-7836.2010.04163.x abstract page 595, left column, paragraph 3; figures 5,6 -----	1-10
A	WO 02/12501 A2 (CENTOCOR INC [US]) 14 February 2002 (2002-02-14) page 1, lines 5-11 page 42, lines 9-10 page 33, lines 27-29; claim 14 -----	1-10
X	WO 2012/007137 A1 (MERCK PATENT GMBH [DE]; KERBER ANNE [DE]; BAEUERLE TOBIAS [DE]) 19 January 2012 (2012-01-19) page 139, line 25-page 140, line 13; claims 1,6; examples 1,8,14 -----	9,10
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International application No

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