Vol 11| Issue 2| 2021 | 57-63.

e-ISSN 2248 – 9142
print-ISSN 2248 – 9134

International Journal of
Current Pharmaceutical & Clinical Research

www.ijcpcr.com

VARIOUS HUMAN FACTORS INFLUENCE THE ADHESION OF STAPHYLOCOCCUS AUREUS TO CENTRAL VENOUS CATHETERS

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ABSTRACT

Staphylococcus aureus is typically the pathogen responsible for infections of the bloodstream that are brought on by the use of catheters (CRBSI). In order to treat the infection, it is typically necessary to remove the implanted medical device. This is due to the fact that the bacteria are capable of forming multilayered biofilms on the material that has been implanted. In order for this biofilm to form, the bacterium must adhere to the artificial surface. The biofilm will not form until this step is complete. This is an essential part of the process. This study, in particular, observed how Staphylococcus aureus adheres to central venous catheters by using single-cell force spectroscopy (SCFS). In SCFS experiments with S. aureus, maximum adhesion forces were found to be comparable on three different types of CVCs (between 2 and 7 nN). This was the case when comparing the adhesion forces. These values dropped by a sizeable amount after the surfaces of the CVCs were subjected to a preincubation Human serum albumin or blood plasma. When fresh CVCs withdrawn from patients were examined for S. aureus cells who did not have CRBSI, similar reductions were observed in the number of bacterial colonies. According to these findings, once the central venous catheter (CVC) has been inserted into the vein, the S. aureus is significantly, and negatively, affected by CVC tubing. Blood plasma or serum albumin can be used to precondition CVC tubes, it may be possible to reduce the chances of Staphylococcus aureus contaminating the CVC during insertion.

Key words: Microbiology, Pathogenesis, Materials Science.

INTRODUCTION

The gram-positive bacterium known as S. aureus1 is frequently to blame for infections that are brought on by medical devices. It forms multilayered biofilms that are resistant to antibiotic treatment, as well as adhering to many different kinds of artificial surfaces. The central venous catheter, also known as a CVC, is a type of endovascular medical device that is frequently used and is of the utmost importance in the treatment of patients in general medical practise, especially those who are being cared for in intensive care units3. However, there is a significant risk of bloodstream infections (BSIs) associated with the utilisation of CVCs, and at the present time, staphylococcus aureus is the most common cause of bloodstream infections that are associated with catheters (CRBSIs). In terms of durability, polyurethane outperforms silicone; however, this advantage comes at the expense of increased bacterial colonisation rates5. The two materials that are utilised the most frequently in the manufacturing of CVC are silicone and polyurethane (PU), with PU exhibiting a greater degree of permanency than silicone does. Researchers conducted a number of studies in the 1980s and 1990s with the purpose of determining the host- and pathogen-related factors that are responsible for the adhesion of S. aureus to CVCs6–11. These studies were carried out during the decades of the 1980s and 1990s. These studies came to the conclusion that cell wall-anchored proteins and associated adhesins are among the most important adhesins that S. aureus utilises in order to adhere to naive catheters.

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Studies with Staphylococcus epidermidis demonstrated that adhesion of the bacterium to the implant material is also driven by surface hydrophobicity and -topology, and it is likely that this also holds true for S. aureus16. The studies were conducted with Staphylococcus epidermidis. Staphylococcus epidermidis was utilised in the research that was carried out. According to the findings of other studies, the ability of catheters to bind S. aureus to polymer surfaces is significantly affected by host factors that have been deposited on the catheters. These host factors have been found to have a positive effect on the capacity of catheters to bind S. aureus to polymer surfaces. CVC surfaces quickly become coated with plasma proteins after being inserted into the vasculature (within seconds). A consequence of this change is an altered capacity of the bacteria to attach themselves to the implanted device17. The effect that a plasma surface coating has on the degree to which S. aureus adheres to polyurethane and chlorinated vinyl chloride is, however, the subject of some debate in the scientific literature. Plasma was found to have a positive effect on the ability of S. aureus to adhere to PU-based catheters in some studies; however, plasma or serum was found to have no effect, or even a negative effect, on the ability of this bacterium to adhere to PU-based catheters in other studies. In some studies, plasma was found to have a positive effect on the ability of S. aureus to adhere to PU-based catheters; in other studies, S. aureus adhesion studies were performed with untreated and explanted CVCs. Considering the results from these studies, it is reasonable to conclude that host factors deposited on the CVC during implantation may serve to enhance rather than inhibit the attachment of S. aureus to the implanted intravascular device. This presumption is founded on the fact that adhesion studies with S. aureus were conducted using CVCs that had not been treated in any way.

It is necessary for the bacterium to have direct physical contact with the medical device before it can successfully colonise and produce a biofilm on the CVC. It's possible that this will take place through a variety of different routes or channels. It is possible that the bacterium will come During insertion of the central venous catheter through the skin (CVC), the skin comes into contact with the catheter. The CVC is naive and could easily come into contact with the bacterial cell living on the skin in these conditions as a result of the interaction of physicochemical forces and capillary forces. It is a widely held belief that the majority of catheter-related bloodstream infections (CRBSIs) that occur as a result of short-term central venous catheters (in place for less than 10 days) originate from the skin and gain access extraluminally. Another common way in which S. aureus can make its way into contact with the central venous catheter is through the Through the device, fluid is contaminated. The CVC will come into contact with native Staphylococcus aureus cells as long as its luminal area is either not coated (i.e. the tubing of the CVC), or is covered with plasma factors. Regardless, native S. aureus cells will be in close proximity to the apex of the CVC (the front tubing and the tip). Thirdly, S. aureus can colonize CVCs via the bloodstream, and this technique is more likely to originate from sources located far away than the ones that can cause local infections (hematogenic spread). As a result, CVC surfaces that are also covered with plasma factors will come into contact with S. aureus cells that have been decorated with plasma factors. This will cause the S. aureus cells to acquire plasma factor decorations. There is an extremely low amount of information that is currently available about the ways in which these colonisation routes can influence the Kinetics of adhesion between Staphylococcus aureus and implanted medical devices. To continue in this vein, to the best of our knowledge, the adhesion forces that exist. The implant material and the bacterial cell have not yet been determined. Staphylococcus aureus could initially adhere better to CVC surfaces if blood plasma is present. This has not been investigated. This study utilized single-cell force spectroscopy (SCFS) to examine the rupture lengths and adhesion forces of PU-based CVCs coated with plasma as well as naive Staphylococcus aureus cells adhered. Previously uncovered gaps in the research were filled with this study. Using this test, the An analysis of the adhesion and rupture forces of viable S. aureus cells, native cells, and plasmodextrin coated cells could be determined.

RESULTS AND DISCUSSION

Surface characteristics of chlorvinyl chloride (PVC) tubing with a polyurethane-based coating

Previous research conducted by our team demonstrated that hydrophobic and Bacterial interactions with artificial surfaces via hydrophily are responsible for the majority of staphylococci's ability to adhere to abiotic surfaces. In addition, the results of our studies demonstrated that S. aureus exhibits greater adhesion forces on hydrophobic surfaces as compared to hydrophilic surfaces24. Surface topology is an additional important factor that affects S. aureus's ability to bind to an abiotic surface25. Surface topology can be thought of as the "map" of the surface. According to several recent studies, the adhesion of S. aureus to surface roughness measurements of silicon or titanium wafers falls off sharply with smaller surface roughness measurements (i.e. 20 nm). However, it has been reported that variations in the surface topography of surfaces in the micrometre to nanometre (m) range (350 nm) can enhance bacterial adhesion to a substrate.

It is unfortunate that, although PU-based catheters are the majority of catheters Roughness and other properties of this line are unknown since it is used for central lines of commercially available PU-based catheters, and these characteristics may also vary significantly between manufacturers. The majority of central lines are currently PU-based catheters despite this being the most common type of catheter currently being used. Researchers first examined

the topography of three distinct CVC types obtained from different manufacturers, as well as their hydrophobicity and hydrophilicity, at the Saarland University Medical Hospital. This was done in order to gain a better understanding of these characteristics. These CVCs are available in a wide range of dimensions and configurations. These surfaces are hydrophobic, as shown by the fact that advancing water contact angles in the range of 90° to 130° were exhibited by all three types of CVC (Table (Table1). The overall roughness of the surfaces of all three CVC tube specimens was fairly comparable to one another in a similar manner. Roughness values for the samples (Table 1) ranged from 51 to 58 nm in root mean square (RMS). The surface topologies of the three types of CVC appear to be noticeably different from one another, however, based on the height profiles recorded by AFM at 10 m and 10 m, respectively. CVC surfaces of type III had noisy surface topologies, which included a great number of humps and valleys in addition to a great number of small peaks. The differences in height between these features could be as much as 500 nanometers (nm). Compared to type II CVC surfaces, type I surface topologies had the most bumps, but the fewest variations between bumps and valleys. Unlike type III CVC surfaces, type II CVC's topology was flatter with elevated bumps. Based on the AFM images, skewness, which quantifies the degree of asymmetry of the surface height distribution, was found to be a more significant factor for surfaces of type II, while the other surfaces showed lower skewness values that were within a comparable range (Table (Table1). These findings confirm earlier research that suggested CVC type II exhibited a surface topology that was more irregular than that of CVC types I and III. These results are consistent with those earlier findings.

Types 1-III of CVC tubing surface characteristics.

	This type of CVC		
	I	**II**	**III**
Raising the contact angle of water (°)	121 ± 5	110 ± 1.22	109 ± 1.35
Surface roughness (nm)	56.5 ± 2.55	49.8 ± 2.21	58.3 ± 5.27
Inequalities	0.63 ± 0.25	1.72 ± 0.68	0.43 ± 0.2

The mean * standard deviation represents the data.

S. aureus demonstrates adhesion forces on a variety of PU-based CVC surfaces that are comparable to those exhibited by other types of bacteria.

Staphylococci adhesion to CVCs has been investigated quantitatively and qualitatively in a number of studies, but the adhesion forces between S. aureus and these kinds of implant materials have not yet been determined. In order to take the next logical step, we investigated the adhesion behaviour of viable S. aureus cells to the surfaces of the CVC using SCFS. By using this technique, which has a force resolution of pN 21, scientists are able to measure the forces exerted by a single bacterial cell against its substrate. As expected from our surface characterization experiments, which exhibited an average of 3.1 2.3 nN and 4.0 2.9 nN (mean and standard deviation). However, N315 cells did not have a statistically significant difference on the CVC surface of type II. In the same way, rupture lengths were approximately half as long for N315 on the surface of type II CVC as they were for N315 on the surface of type III CVC. On the type II CVC surface, these rupture lengths were observed. These results are similar to those that were discussed in the previous paragraph (Table 1).

In order to rule out the possibility that our findings with N315 might be unique to this strain, we performed a CRBSI-related clinical isolate HOM433 was the subject of the second series of SCFS measurements. Staphylococcus aureus adhesion tests on CVC surfaces16 were conducted as part of our study, and these confirmed that the N315 findings did not apply to other strains. The purpose of this analysis was to determine if the findings obtained with strain N315 could potentially be attributed to another strain. Cells from the Various surfaces of the nave CVC were probed to examine Fadh values and rupture lengths of 3 clinical isolates to be extremely comparable on each type. This suggests that a number of bacterial adhesins are involved and that the surface components of the bacterial cell attached to the CVC surface begin to separate rather rapidly23,24. Several adherent forces were measured for S. aureus N315 on PU-based CVC surfaces that were comparable with those observed for this bacteria on silicone rubber. Because polyurethane vinyl chloride was used on both surfaces, this finding was possible. The adhesion forces for titanium were similar to those of copper, but were about a factor 10 higher (J. Mischo, unpublished data). Orthopaedic and dental implants31 are commonly made of titanium. As a result, the binding force S. australis shows on naive PU-based CVC surfaces is the same strength as its binding power.

Previous research23 describing the adhesion of Staphylococcus aureus to hydrophobized silicon wafers with very smooth surfaces found force-distance measurements with individual bacterial cells to be highly superimposable. Although some cells in our experiment showed considerable variations in maximum adhesion forces, all of the other cells did not. Although each cell had a very smooth surface topography, this was still the case. A number of individual

cells showed differences in adhesion forces when measured for maximum adhesion. This discovery may have more than one possible explanation; one of those explanations involves the surface roughness of the CVC tubes that were evaluated. We also determined the maximum adhesion forces that N315 cells have when they are placed on a hydrophobic glass surface called Fluoro Dish. This surface has a low surface roughness (RMS = 1.1 0.2 nm) and does not have any major humps. This was done in order to determine how much of an impact surface roughness has on the amount of variation in adhesion force that can be seen between repeated measurements using the same bacterial probe. According to the results of our research, surface roughness is likely a factor that contributes to the wide range of adhesion forces observed for different materials. Alterations in surface composition, which can be brought about by both chemistry and biomechanics, provide yet another possible explanation for this phenomenon. Materials made of polyurethane take the form of block copolymers, which are composed of multiple phases with different physical and chemical properties. This formation of a two-phase microstructure is what leads to the formation of PU-based materials. It has been demonstrated that different adsorption patterns are exhibited by these microdomains in relation to plasma proteins and cell attachment.

When repeated measurements were made using the same bacterial probe, significant variations in adhesion forces were also observed between individual cells in part similar to the variations observed in adhesion forces when repeated measurements were made using the same bacterial probe. Variations in adhesion forces seen in repeated tests are analogous to what was observed in repeated adhesion force measurements. This observation is made in a relatively high proportion of SCFS studies involving staphylococci. It is highly likely that this is because of the variations that take place from cell to cell, and the results from individual cells taken from the same cell culture at the same time are equivalent.

The use of precoating with human blood plasma on the CVC surface was found to significantly reduce the amount of force required for S. aureus to adhere to the surface of the CVC.

Immediately after implantation, blood plasma factors 36 decorate implanted materials exposed to the bloodstream. After they have been exposed to the blood, they are decorated with these factors. In contrast, however, it is unclear whether this positively or negatively impacts the ability of Staphylococcus aureus to adhere to implanted medical devices. It has not been thoroughly investigated how Staphylococcus aureus adheres to the surfaces of CVCs. Although this is of key importance. SCFS was performed using S. aureus N315 incubated with human blood plasma for thirty minutes prior to SCFS. We began by determining the maximum adhesion forces for N315 on the surfaces of CVC tubes that had been precultured in PBS for thirty minutes. Since PU-based materials generally change their surface properties when exposed to aqueous solutions34, we compared them to the values for N315 exposed to aqueous solutions. Aqueous solutions can cause surface property changes in PU-based materials. Hence, thirty minutes of contact with aqueous solutions was enough to cause changes in surface properties of polyurethane-based CVCs that either increased (CVC-types I and II) or decreased (CVC-type III) the adhesion of S. aureus. [Citation needed]

As a result of these findings, it is highly likely that the ability of S. aureus to adhere As soon as the CVC is inserted into the vein, the level of infection is dramatically reduced, which confirms earlier research demonstrating a negative correlation between plasma or serum and S. aureus and polymer materials. After CVCs are inserted, there is substantial evidence that Staphylococcus aureus is less likely to adhere to these types of medical devices. In addition, the results indicate that Staphylococcus aureus's ability to adhere to an intravenous catheter is severely reduced after the catheter is inserted. This conclusion can be drawn from the fact that the findings have been drawn.

The higher surface hydrophobicity on HBP-precoated CVC surfaces may be one factor that contributes to the lower Fadh values observed for S. aureus on those surfaces. Because S. aureus has a lower capacity to adhere to hydrophilic surfaces, this could be one explanation for why the Fadh values are lower. As a result, as the next step in the process, we investigated how an HBP preconditioning influenced the amount of moisture that was present in the CVC tubing. Water contact angles with pretreated CVC types I, II, and III that were pretreated with HBP were respectively 55.4%, 39.4%, and 51.5%. The HBP preconditioning achieved a significant alteration in the hydrophobicity of the CVC tubing. On CVC tubing precoated with HBP, Staphylococcus aureus might have a decreased maximum adhesion force. Based on these results, preconditioning the CVC tubing with HBP results in a change from hydrophobic to hydrophilic surfaces. It would seem, however, that interactions between blood plasma factors deposited on the CVC tubing and specific receptor-ligand combinations such as those that occur between bacteria and their cell walls are of relatively little importance. Although Staphylococcus aureus possesses several adhesins that attach to the cell wall, these enzymes are not able to attach A common example of plasma factors that are affected are fibrinogen (Fg), fibronectin, immunoglobulin G, vitronectin, and von Willebrand factor (vWF).

S. aureus displayed only a moderate amount of adhesion forces when it was grown on explanted CVC tubings

It is common knowledge that the flow conditions as well as the dwelling times can both have an effect on It can also alter the conformation of proteins that are adsorbing to plasma factor coatings36. Clearly, the adherence forces of strains N315 and HOM433 to freshly explanted CVC tubing

from patients without CRBSI were very similar to the Fadh values we were able to determine on in vitro preincubated CVC surfaces using N315 and HOM433, so our in vitro study results match our in vivo results. The purpose of this study was to determine whether our findings were acceptable in vitro and how well they were received.

Using HBP factors to coat the cell walls of Staphylococcus aureus, it was found that the adhesion force of the bacterial cells to the surface of the CVCs precoated with HBP was diminished to an even greater extent.

Hematogenous spreading is a third method that S. aureus can use to colonise CVCs. This method occurs when the bacterium spreads from one infection foci41 to another. S. aureus can colonise CVCs using this method. When these conditions are met, the surface of a CVC that is also covered with plasma factors and blood cells is brought into contact with In S. aureus cells, plasma factors can be found on the surface and/or attached to blood cells. Preconditioning the bacterial cells with HBP significantly decreased the In comparison to the adhesion forces between uncoated N315 cells on preincubated CVC surfaces, maximal adhesion force between N315 and the HBP-coated CVC surface. This was observed compared with the adhesion forces on CVC surfaces preincubated with HBP uncoated N315 cells. In light of these results, it appears that bloodborne S. aureus cells are less able to adhere to surfaces of CVCs that have been inserted into the vasculature, at least under static conditions. This conclusion is based on the fact that when the conditions were static. However, the experimental setup that we have does not include at least two major factors that are important for the adhesion of S. aureus to implant material that is inserted into the vasculature. This is a limitation of the current study. The presence of blood cells, such as platelets, that are adhered to the surface of the catheter, which the bacterium may use for adhesion, is one of these factors. Another factor is shear flow. Our investigation does not take into account either of these two factors. It has been demonstrated that S. aureus cells are able to adhere to platelets in an effective manner, and it has been demonstrated that platelets adhere to implanted material that has been inserted into the bloodstream. Both of these phenomena have been demonstrated. In spite of Despite not knowing the extent to which S. aureus adheres to blood-exposed implant materials via platelets, it would probably be a safe assumption that platelets contribute to the adhesion and biofilm formation of S. aureus to/on CVCs, given the interaction of S. aureus with these types of blood cells. This is because S. aureus and platelets interact with one another. Despite the fact that it is not yet known to what extent S. aureus adheres to blood-exposed implant material, this is the case nonetheless. Shear flow is an additional factor that has the potential to play an important role in the ability of S. aureus to bind to implant material that is inserted into the vasculature. This potential can be seen in the fact that this factor has the potential to play an important role. High shear stress is applied to the majority of the regions of the CVC tubing that are inserted into larger veins. This type of stress can cause the tubing to fail. The binding of S. aureus to activated endothelium in the presence of high shear flow has been shown to be predominantly mediated by elongated vWF fibers. This was demonstrated by both ourselves and others. During these experiments, CVC tubing was inserted into larger veins so that the procedure could be carried out. Unfolding of vWF can only be observed in circumstances in which vWF is tethered to a surface and is then subjected to high shear stress. This is the only circumstance in which unfolding of vWF can be observed. It is also common knowledge that vWF can adsorb on catheters even when they are not in contact with blood. vWF does not appear to have a significant effect on platelet adhesion to blood-exposed implant materials, however, its extended form may play an important role in inhibiting an adhesion of S. aureus to such implant materials when flow is high. It is essential to precisely determine the flow profile to be able to observe shear flow-induced phenomena (for example, using particle imaging velocimetry with a microfluidic setup). These activities are not included in the study that is currently underway.

The adhesion force of S. aureus to the surfaces of the CVC is significantly reduced when the CVC tubing is pre-incubated with serum albumin or Fg. This results in a significant improvement in patient outcomes. Among the primary proteinaceous plasma factors adsorbing to blood-exposed areas of polymers are serum albumin and Fg. Using serum albumin before preincubating a CVC has been shown to reduce the adhesion of Staphylococcus aureus to the surface of the CVC. Following preincubation of the catheter fragments with 40 mg/ml of HSA, which is the concentration of albumin found in human blood, the adhesion force of N315 on the CVC surface decreased by about 35. As discussed above, HSA has a concentration of 40 mg/ml. These are the results that were obtained after measuring N315's adhesion forces on the CVC surface. The results of this study showed that these blood plasma proteins inhibited the adhesion of Staphylococcus aureus to PU-based CVC surfaces at concentrations considerably lower than those found in human blood. This is the conclusion that can be drawn from the fact that concentrations of this protein in human blood are significantly higher than those found in blood plasma.

When earlier research was conducted, it was discovered that Fg had a positive effect on the ability of S. aureus to adhere to implanted materials when they were subjected to quantitative adhesion assays. Therefore, this most recent observation comes as a surprise. In our hypothesis, the presence of physiological concentrations of Fg on a CVC surface will decrease the force of interaction between S. aureus and the implanted material, whereas the presence of this host factor on the CVC surface will enhance the comparative adhesion capacity of S. aureus to this implant. This is because the interaction force between S. aureus and the implanted material is proportional to the

interaction force between S. aureus and the implanted material. As a result, Fg has a distinct effect on both the qualitative and quantitative adhesion of S. aureus to the implanted material in vitro. As described in this scenario, human blood plasma may also be exposed to the factors that are adsorbing on the surface of the CVC. These factors contributed significantly to the reduction of Staphylococcus aureus and PU-based CVCs in this study. Researchers have found that different catheter surfaces contain more Staphylococcus aureus cells. Conversely, to determine whether S. aureus adhered to the explanted fragments of catheters that had been coated with serum albumin, sample fragments of catheters that had not been precoated with serum albumin were tested. Because of this, the question of whether S. aureus would have adhered directly to the various naive catheter fragments remains unanswered, so we must ask more questions.

Conclusions

A major nosocomial pathogen and a commonly implanted medical device were studied in order to determine their adhesion forces. This is the first instance, as far as we are aware, that SCFS with S. aureus has been conducted on real, commercially available CVC materials. Several studies have shown that PU-based CVC tubing is a particularly good adhesion medium for S. aureus, and that the adhesion can be significantly reduced by treating the tubing with blood plasma or serum albumin before use. Our research was recently featured in an issue of the journal Microbiology. It has been suggested that preconditioning the surface of the CVC with serum albumin, which is a procedure that has been suggested to reduce the risk of thrombus formation on blood-exposed medical devices, might also be a valid tool for decreasing the risk of contamination of the CVC tubing with S. aureus, particularly during the process of insertion. This is because preconditioning the surface of the CVC with serum albumin is a procedure that has been suggested to reduce the risk of throm. This is due to the fact that it has been suggested that preconditioning the surface of the CVC with serum albumin is a procedure that can reduce the risk of thrombus formation on blood-containing surfaces. It is likely that a decrease in surface hydrophobicity of the implant material evoked by the adsorbed plasma factors is the cause of the decreased Blood plasma precoated PVC tubing is a good medium to adhere Staphylococcus aureus cells to. Consequently, the implant material's surface hydrophobicity decreases as a result of the adsorbed plasma factors. Initially, the study looked at various catheter types and Staphylococcus aureus to test this hypothesis. The results of these studies showed that chemically modified catheters rendered less hydrophilic also had a reduced quantity of bacterial adhesion to the modified surfaces. As this assumption is consistent with earlier findings, this presumption is supported. This finding lends credence to the hypothesis that enhancing the hydrophilicity of PU-based CVC tubing could be an effective method for reducing the possibility of bacterial colonisation of an implanted medical device. In addition, the findings of our investigation suggest that a chemical alteration of the surface of the tubing may not be required in order to realise this goal.

REFERENCE:

1. Hogan S, Stevens NT, Humphreys H, O'Gara JP, O'Neill E. Current and future approaches to the prevention and treatment of staphylococcal medical device-related infections. *Curr. Pharm. Des.* 2015;21:100–113.
2. Lebeaux D, Ghigo JM, Beloin C. Biofilm-related infections: bridging the gap between clinical management and fundamental aspects of recalcitrance toward antibiotics. *Microbiol. Mol. Biol. Rev.* 2014;78:510–543. doi: 10.1128/mmbr.00013-14.
3. Safdar N, Maki DG. Inflammation at the insertion site is not predictive of catheter-related bloodstream infection with short-term, noncuffed central venous catheters. *Crit. Care Med.* 2002;30:2632–2635. doi: 10.1097/01.ccm.0000037966.19604.25.
4. Lai YL, et al. Dwindling utilization of central venous catheter tip cultures: an analysis of sampling trends and clinical utility at 128 US hospitals, 2009–2014. *Clin. Infect. Dis.* 2019;69:1797.
5. Wildgruber M, et al. Polyurethane versus silicone catheters for central venous port devices implanted at the forearm. *Eur. J. Cancer.* 2016;59:113–124. doi: 10.1016/j.ejca.2016.02.011.
6. Francois P, et al. Physical and biological effects of a surface coating procedure on polyurethane catheters. *Biomaterials.* 1996;17:667–678.
7. Vaudaux P, et al. Fibronectin is more active than fibrin or fibrinogen in promoting *Staphylococcus aureus* adherence to inserted intravascular catheters. *J. Infect. Dis.* 1993;167:633–641.
8. Vaudaux P, et al. Host factors selectively increase staphylococcal adherence on inserted catheters: a role for fibronectin and fibrinogen or fibrin. *J. Infect. Dis.* 1989;160:865–875.
9. Cheung AL, Fischetti VA. The role of fibrinogen in staphylococcal adherence to catheters in vitro. *J. Infect. Dis.* 1990;161:1177–1186.
10. Barrett SP. Protein-mediated adhesion of *Staphylococcus aureus* to silicone implant polymer. *J. Med. Microbiol.* 1985;20:249–253. doi: 10.1099/00222615-20-2-249.

11. Espersen F, Wilkinson BJ, Gahrn-Hansen B, Thamdrup Rosdahl V, Clemmensen I. Attachment of staphylococci to silicone catheters in vitro. *APMIS.* 1990;98:471–478.
12. Paulsson M, et al. Adhesion of staphylococci to chemically modified and native polymers, and the influence of preadsorbed fibronectin, vitronectin and fibrinogen. *Biomaterials.* 1993;14:845–853. doi: 10.1016/0142-9612(93)90006-N.
13. Ludwicka A, Jansen B, Wadstrom T, Pulverer G. Attachment of staphylococci to various synthetic polymers. *Zentralbl. Bakteriol. Mikrobiol. Hyg. A.* 1984;256:479–489.
14. Locci R, Peters G, Pulverer G. Microbial colonization of prosthetic devices. III. Adhesion of staphylococci to lumina of intravenous catheters perfused with bacterial suspensions. *Zentralbl. Bakteriol. Mikrobiol. Hyg. B.* 1981;173:300–307.
15. Tebbs SE, Sawyer A, Elliott TS. Influence of surface morphology on in vitro bacterial adherence to central venous catheters. *Br. J. Anaesth.* 1994;72:587–591.