Staphylococcus epidermidis: A Commensal Emerging As A Pathogen With Increasing Clinical Significance Especially In Nosocomial Infections

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Citation

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Abstract

S.epidermidis lives naturally on the skin and mucous membranes.
While at one time the appearance of S.epidermidis in clinical material could be
dismissed as contamination, it is now one of the most important agents of
nosocomial infections especially in immunocompromised individuals, neonates and
patients with internal prosthetic devices. In these patients, the infection result from a compromise in both general and local defense mechanism, and inability to clear staphylococci from infected device because of a biofilm on the foreign body surface.
Distinguishing, clinically significant pathogenic strains from contaminant
strains is one of the major challenges facing clinical microbiologists. Because many isolates are multiply antibiotic resistant, their infections are difficult to treat and can even be fatal.
A detailed characterization of isolates of S.epidermidis strains through
speciation, genetics and antibiotic susceptibility may be necessary to
distinguish infecting from contaminating isolates and to plan suitable therapy.

INTRODUCTION

Coagulase negative staphylococci (CNS) constitute a major component of the normal skin and mucosal microflora[1].

They are commonly isolated in clinical specimens and many are identified as important agents of hospital acquired infections especially in immunocompromised individuals, neonates and patients with internal prosthetic devices[2,3].

CNS were considered as harmless skin commensal and dismissed as culture contaminants, but in recent years, they are increasingly being recognized as important human pathogens [1].

Among all CNS, Staphylococcus epidermidis strains represent the most frequent cause of nosocomial sepsis and the most common agents of infections with implanted medical evices[4].

MOLECULAR MECHANISM OF BIOFILM FORMATION

A characteristic of many pathogenic strains of S.epidermidis is the production of slime resulting in biofilm formation[5]. The slime is predominantly a secreted teichoic acid, normally found in the cell wall of the staphylococci[6]. This ability to form a biofilm on the surface of a prosthetic device is probably a significant determinant of virulence for these bacteria [7]. Biofilm may serve to protect the organism from host phagocytic mechanism and improve the local nutritional environment[8].

Recently, the genetic control of the slime production has begun to be elucidated, first in the S.epidermidis and then in Staphylococcus aureus. Synthesis of the capsular polysaccharide is mediated by the ica operon (intercellular adhesion gene cluster)[9].

It appears that bacterial adherence is a complex multistep process that is influenced by the host, the device and the microbe. The adherence process is sub divided into the following stages: attachment, adhesion and aggregation[8].

The primary attachment of S.epidermidis to a polystyrene surface is related to a cell surface protein exhibiting

vitronectin binding activity[10].

The later phases of adherence, in which organisms adhere to one another and elaborate biofilm, are mediated by polysaccharide intercellular adhesin (PIA), which is synthesized by products of the chromosomal ica gene locus, which comprises intercellular adhesion genes (ica A, ica D, ica B, and ica C) organized, in an operon [11,12, 13,14].

Mutants lacking PIA are less virulent in an animal model for foreign body infection and immunization with purified PIA is protective[15].

Sub inhibitory concentrations of tetracycline and the semi synthetic streptogramin antibiotic quinupristin-dalfopristin were found to enhance ica expression 9 to 11 fold, whereas penicillin, oxacillin, chloramphenicol, clindamycin, gentamycin, ofloxacin, vancomycin and teicoplanin had no effect on ica expression. A weak (2.5 fold) induction of ica expression was observed for sub inhibitory concentrations of Erythromycin[16].

S.epidermidis strains from clinical materials appears to differ from saprophytic strains by the presence of the ica A and ica B genes, their capacity for phase variation, their abilities to adhere to polymer and autoaggregate and in their colony morphology on congo red agar[17].

INFECTIONS

BACTEREMIA

S. epidermidis and other CNS are the most frequently reported pathogens in nosocomial blood stream infections[1].

According to the Centers for Disease Control and Prevention's National Nosocomial infection surveillance system; S. epidermidis is responsible for 33.5% of nosocomial blood stream infections[18].

These bacteremias are largely due to intravascular associated infection. Unfortunately, nosocomial bacteremia due to S. epidermidis is a rapidly increasingly problem [5, 19, 20].

A study has demonstrated that the isolation of CNS was attributed to the colonization of the implanted catheter since the same microorganism had been isolated from the blood of patients during the preceding weeks, some of them with multiple positive cultures[21].

It is known that mucosal damage of the alimentary tract and concurrent colonization of mucous membranes are risk factors for S. epidermidis infections [22]. Colonization of the gut and skin with antibiotic resistant S. epidermidis can follow the intensive use of oral and systemic antimicrobials[23].

Bacteremia originating from these sites can result from a compromise in both general and local defense mechanism in severely immunocompromised patients.

S. epidermidis frequently contaminate blood cultures making their interpretation a major concern for clinicians and for microbiologists. Although, criteria such as, sepsis symptoms, the number of positive blood cultures from separate venipuncture or access site and the similarity of their antibiotic resistance profiles, are often considered 5.

A large proportion of nosocomial isolates of CNS are resistant to multiple antibiotics, including penicllinase resistant penicillins[24].

Localized infections with positive blood cultures are associated with higher mortality rate than localized infections without positive blood cultures[25].

INFECTIONS ASSOCIATED WITH MEDICAL DEVICES

S. epidermidis is the most prominent cause of intravascular catheter associated infection[19].

In one study it was demonstrated that two clones of S. epidermidis were predominantly involved in colonization and subsequent infection in neutropenic hemato-oncologic patients in a setting with a high incidence of Catheter Related Infection (6.0/1000 catheter days), and a very high catheter removal rate for CRI, 70%, despite prompt treatment with vancomycin. They seem to have persisted for a period of at least 5 years in the hematology department[26].

At insertion, these clones constituted 13% CNS isolated from air samples and 44% CNS isolated from skin cultures.

After insertion, their combined prevalence increased to 53% in catheters not associated with CRI and 74% in catheters associated with CRI.

A likely source of S. epidermidis strains involved in CRI appeared to be the skin flora in 75% of cases [26].

As 94% of these two predominant strains were ciprofloxacin resistant and all patients received selective antimicrobial prophylaxis with ciprofloxacin, these strains possessed a

selective advantage.

Perhaps sub inhibitory concentration of ciprofloxacin is able to promote adherence of these two S.epidermidis clones, as has been described recently for S. aureus [27].

However, in earlier studies, adherence of a variety of CNS strains was reduced after incubation with sub inhibitory concentration of ciprofloxacin[28].

Migration of skin organisms at the insertion site into the cutaneous catheter tract with colonization of the catheter tip is the most common route of infection for peripherally inserted, short-term catheters [29,30].

Some catheter materials have surface irregularities that enhance the microbial adherence. Additionally, certain catheter materials are more thrombogenic than others, a characteristic that also might predispose to catheter colonization and catheter related infection[29].

Teflon or polyurethane catheters have been associated with fewer infectious complications than catheters made of polyvinyl chloride or polyethylene[31].

Contamination of the catheter hub contributes substantially to intraluminal colonization of long-term catheters and implicated as an additional entry point leading to catheter related sepsis justifying local use of antibiotics in preventive control measures[29, 32].

Rarely, catheter might become hematogenously seeding from another focus of infection [29, 30].

It might be possible to eradicate methicillin resistant CNS at the site of catheter implantation by using antiseptics and to prevent ingress of CNS by a combination of occlusive dressings and careful handling of catheters and insertion sites with gloved hands[22].

ENDOCARDITIS

Coagulase negative staphylococci, usually S.epidermidis, previously a minor cause of native valve endocarditis, are an important cause of prosthetic valve endocarditis and nosocomial infective endocarditis. Nosocomial native valve infections generally result from infected intravascular devices; the affected valve may or may not have been previously abnormal[33,34].

S. epidermidis, are the predominant cause of nosocomial prosthetic valve endocarditis, can be acquired in the theatre (or shortly thereafter) at the time of the original valve replacement and presents within weeks or more often diagnosed within 60 days after surgery (early onset) and the cause of 3 to 8% of native valve endocarditis cases, usually in the setting of prior valve abnormalities[34, 35, 36].

The vast majority of CNS causing PVE, when speciated were S.epidermidis.

In contrast, when infection involves native valves, only 50% of isolates were S.epidermidis [35, 36].

Prosthetic infection can also be acquired from an infected intravascular device.

Nosocomial staphylococci tend to be multiple resistant.

Community acquired endocarditis, which may involve native (usually) or prosthetic valves, is increasingly recognized. Most patients with native valve infection have a pre-existing cardiac abnormality.

The organism must derive from the patient's skin but predisposing skin lesions are seldom detected. The infection often mimics S. aureus endocarditis with rapidly destructive valvular disease, neurological manifestation and concomitant vertebral osteomyelitis.

The commonest pathogen is S. epidermidis, but there are increasing reports of other species, particularly S.lugdunesis, which seems to be especially virulent. These community acquired strains are frequently penicillin sensitive[37].

Some cases of endocarditis following implantation of a prosthetic valve were recently shown to be attributable to polyclonal S.epidermidis populations[38]. Therefore, the detection in samples from the same patient of S.epidermidis strains with different antibiograms does not necessarily indicate contamination of the samples during collection.

Complications, such as dehiscence of the valve or obstruction, are relatively common.

Blood cultures are usually positive and diagnosis is occasionally difficult. Antibiotic treatment of prosthetic valve endocarditis due to S.epidermidis is often inadequate and additional surgical intervention is required in most cases [39, 40].

URINARY TRACT INFECTIONS

S.epidermidis is the predominant species cultured form the

urine in significant numbers (104 cfu/ml), accounting for 80-90% of non S.saprophyticus CNS isolates.

It is cultured almost exclusively from the urine of hospitalized patients with complications of the urinary tract. About half of them have an indwelling urinary catheter.

Both males and females are equally affected and most patients are 50 or more years of age. In at least half of the cases, the organisms are multiple drug resistant[41].

EYE INFECTIONS

S. epidermidis is commonly cultured from the conjunctive and lid margins of normal subjects [42].

Because of its ubiquitous nature and relatively low virulence, S. epidermidis has received so far little attention for its role in ocular infections. However, in different studies

S. epidermidis has been reported to play a significant role in several ocular external diseases such as chronic blepharitis and suppurative keratitis [43, 44].

Given the high level broad spectrum activity against most bacteria and the reduced frequency of ocular toxic effects, ciprofloxacin is currently considered the drug of choice in the therapy for bacterial keratitis[45].

However, there is growing evidence for ciprofloxacin resistant ocular strains of S.epidermidis [46].

Vancomycin and teicoplanin are antistaphylococcal antibiotics, to which resistance is rarely seen, and should be considered the drugs of last resort for the therapy of nosocomial gram positive infections[47]. The multiple resistance of S. epidermidis is a recognized problem. It might possibly represent a response to prolonged treatment.

PEDIATRICS

Major advances in perinatal and neonatal care units have significantly improved survival of very low birth weight infants. However late onset nosocomial neonatal septicaemia, after more than 72 hours post delivery, by CNS , the most common organism accounting for more than 50% cases, show multiple antibiotic resistance including resistance to methicillin [48, 49].

CNS are ubiquitous and every human is colonized soon after birth: during invasive procedures these organism may then gain entry to the blood and result in sepsis[50].

There is a clear co-relation between very low birth weight and the risk of a nosocomial infection with CNS[51].

The intensive use of antibiotics in an NICU setting with highly susceptible patients causes selection of multiresistant clones of CNS, which subsequent becomes endemic[52].

S. epidermidis distinct clones can become endemic in NICUs as long as a decade and nosocomial transmission plays an important role in S.epidermidis bacteremia[53].

Quantitative biofilm production significantly greater in strains isolated from either the blood or skin of neonates with S. epidermidis bacteremia[54].

DRUG RESISTANCE

Over the last decades, there has been an enormous increase and emergence of CNS strains particularly S.epidermidis, S.haemolyticus and S.hominis, resistant to the antibiotic methicillin, especially in nosocomial settings[55]. Methicillin resistance/multiple drug resistance has been documented more often in disease causing strains of S. epidermidis than in skin colonizing strains [56].

Most of these strains harbor mec A, the gene encoding the penicillin –binding protein PBP2a, which has decreased affinity for beta lactam antibiotics[57].

Methicillin sensitive S. epidermidis strains should be treated with oxacillin or cefazolin or clindamicin. Methicillin resistance is equivalent to resistance to oxacillin, which is commonly used and extremely effective anti-staph drug, in fact the drug of choice. Methicillin resistant S.epidermidis strains should be treated with vancomycin[58].

Detection of resistance to oxacillin in staphylococci is important to guide the therapy and prevent the patient from being unnecessarily treated with vancomycin, which is an antimicrobial agent that presents therapeutic complications, high costs and may lead to the selection of resistant mutants[59].

In an article of Jukka Hyvarinan et al, the percentage of S.epidermidis isolates resistant to the 20 tested antibiotics was oxacillin (58%), penicillin (82%), amoxicillin/clavulanic acid (34%), cephalothin (4%), cefuroxime (31%), cefotaxime (20%), imipenem (46%), gentamycin (46%), tobramycin (57%), netilmicin (16%), ciprofloxacin (23%), ofloxacin (21%), erythromycin (36%), fusidic acid (27%), clindamycin (34%), chloramphenicol

(19%), rifampin (4%), vancomycin (0%), co-trimaxazole 62%, trimethoprim (53%) [60].

CONCLUSION

Immunocompromised patients are particularly at risk of CNS infections, as are individuals with indwelling catheters or prosthetic devices.

Because many isolates are multiply antibiotic resistant, their infections are very serious and can even be fatal.

The surfaces and materials such as floors and walls of the hospital rooms, stethoscopes, Beds, tables for nursing elements, oxygen tube extreme and oxygen masks[61], may play an important role in the spread of infectious agents including antimicrobial resistant strains of S. epidermidis, so the regular use of disinfectant for their cleaning is advisable.

The early and precise detection of these organisms in hospital environments and in high risk patients such as cardiac surgery patients, preterm newborns or immunocompromised patients, can prevent the contamination of prosthetic devices or indwelling catheters, and may represent a substantial help for the early treatment.

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References

1. Kloos W. E., Bannerman T. L. Update on clinical significance of coagulase -negative staphylococci. Clin. Microbiol. Rev. 1994;7:117-40.
2. Jarlov, J.O. Phenotypic characteristics of coagulase-negative staphylococci typing & antibiotic susceptibility. APMIS. 1999;91:1-42.
3. Kleeman, K.T, Bannerman, T.L, Kloos, W.E. Species distribution of coagulase-negative staphylococcal isolates at a community hospital & implications for selection of staphylococcal identification procedures. J. Clin. Microbiol. 1993;31:1318-21.
4. Mack D, Rohde H, Dobinsky S, Riedewald J, Nedelmann M, Knobloch J.KM, et al. Identification of three essential regulatory gene loci governing expression of S.epidermidis polysaccharide intercellular adhesin & biofilm Infect. Immun.2000;8: 3799-807.
5. Kotilainen P. Association of coagulase negative staphylococcal slime production & adherence with the development & outcome of adult septicemias. J Clin Microbiol. 1990;28:2779-85.
6. http://textbookofbacteriology.net/staph.html
7. Mack D. Molecular mechanism of S. epidermidis biofilm formation. J Hosp Infect.1999;43. Suppl:S113-25
8. Rupp ME, Ulphani J S, Fey P D, Mack D. Characterization of S. epidermidis polysaccharide intercellular adhesion/hemagglutinin in the pathogenesis of intravascular catheter associated infection in a rat model. Infect and Immun. 1999;67(5):2656-59
9. Arciola C.R, Bald assarri L. B, Montanaro L. Presence o f ica A & ica D genes & slime production in a collection of staphylococcal strains from catheter-associated infections. J Clin Microbiol. 2001;39:2151-56.
10. Heilmann C, Hussain M., Peters G, Gotzz F. Evidence for autolysin-mediated primary attachment of S. epidermidis to a polystyrene surface. Mol. Microbiol. 1997; 24:1013-24
11. Heilmann, C., Schweitzer O, Gerke C, Vanittanakom N., Mack D, Gotz F. Molecular basis of intercellular adhesion in the biofilm-forming S.epidermidis. Mol. Microbiol. 1996;20:1083 -91
12. Gerke C, Krafts A, Smuth R, O. Schweitzer, F. Gotz. Characterization of the N- acetylglucosaminyl transferase activity involved in the biosynthesis of the S.epidermidis polysaccharide intercellular adhesin. J. Biol. C hem. 1998;273:18586-94
13. Mack D, Fischer W, Krokotsch A, Leopold K, Hartmann R, Egge H, et al. The intercellular adhesin involved in biofilm accumulation of S.epidermidis is a linear -1,6-linked glucosaminoglycan: purification & structural analysis. J. Bacteriol.1996;178:175-83
14. Mack, D., Siemssen N, Laufs R. Parallel induction by glucose of adherence & a polysaccharide antigen specific for plastic-adherent S.epidermidis: evidence for functional relation to intercellular adhesion. Infect. Immun. 1992; 60:2048-57
15. Timothy Foster. Staphylococcus. http://gsbs.utmb.edu/microbook/ch012. htm
16. Shwan R, Knut O, Wolfgang W, Jorg H, Wilma Z. Effect of Subinhibitory Antibiotic Concentrations on Polysaccharide Intercellular Adhesin Expression in Biofilm-Forming S. epidermidis. Antimicrob Agents Chemother.2000;44(12):3357-63.
17. Ziebuhr, W., C. Heilmann, F. Gotz, P. Meyer, K. Wilms, E. Straube, et al. Detection of the intercellular adhesion gene cluster (ica) & phase variation in S.epidermidis blood cult. strains & mucosal isolates. Infect. Immun. 1997; 65:890-96
18. U.S. Department o f Health & Human Services, Public Health Service. National nosocomial infections surveillance (NNIS) report, data summary from October 1986-April 1997. Am. J. Infect. Control. 1997; 25:477-87
19. Rupp M E, Archer G L. Coagulase-negative staphylococci: pathogens associated with medical progress. Clin. Infect. Dis.1994;19:231-45
20. Banerjee, S. N., T. G. Emori, D. H. Culver, R. P. Gaynes, W. R. Jarvis, T. Horan, et al. The National Nosocomial Infections Surveillance System. 1991. Secular trends in nosocomial primary blood stream infections in the United States, 1980-1989. Am. J. Med. 91(Supp l. 3B) :3B-86S3B8 9S
21. Minto E C, Barelli C, Martinez R, da Costa Darini A. Identification & medical importance of coagulase negative staphylococci species. Sao Paulo Med J. 1999;117(4):175-8.
22. Frebourg NB, Cauliez B, Lemeland JF. Evidence for Nasal Carriage of Methicillin-Resistant Staph Colonizing Intravascular Devices. J Clin Microbio.1999;37(4):1182- 85.
23. Archer GL, Armstrong BC. Alteration of staphylococcal flora in cardiac surgery patients receiving antibiotic prophylaxis. J Infect Dis. 1983;147:642 -9.
24. Archer G L, Climo MW. Antimicrobial susceptibility of coagulase- -ve staph. Antimicrob. Agents Chemother. 1994;38:2231-37

25. Souvenir D, Anderson DE Jr., Palpant S, Mroch H, Askin S et al. Blood cultures positive for coagulase -negative staphylococci: antisepsis, pseudobacteremia, & therapy of patients. J Clin Microbiol.1998;36(7):1923-6
26. Nouwen JL, Alex van Belkum , Siemde Marie, Sluijs J, Wielenga J J, Kluytmans Jan A. J. W, et al. Clonal Expansion of S.epidermidis Strains Causing Hickman Catheter-Related Infections in a Hemato-Oncologic Department: J Clin Microbio. 1998;36(9):2696-702.
27. Bisognano C, Vaudaux PE, Lew DP, Hooper E. Y. W. Ng, D. C. Increased expression of fibronectin-binding proteins by fluoroquinolone-resistant Staph aureus exposed to subinhibitory levels of ciprofloxacin. Antimicrob. Agents Chemother. 1997; 41:906-13
28. Wilco x M H, Finch RG, Smith DG, Williams P, Denyer SP. Effects of carbon dioxide & sub- lethal levels of antibiotics on adherence o f coagulase--ve staph to polystyrene & silicone rubber. J. Antimicrob. Chemother.1991;27:577-87
29. Naomi P. O'Grady, M Alexander, E. P Dellinger, J L. Gerberding, S O.Heard, D G Maki, et al. Guidelines for the Prevention o f Intravascular Catheter-Relate d Infections. PEDI ATRICS. 2002;110(5):e51
30. Salzman M. B., Isenberg HD, Shapiro JF, Lipsitz PJ, Rubin LG. A prospective study of the catheter hub as t he portal of entry for micro organisms causing catheter-related sepsis in neonates. J. Infect. Dis. 1993; 167:487-90
31. Maki DG, Ringer M. Risk factors for infusion-related phlebitis with small peripheral venous catheters: a randomized controlled trial. Ann Intern Med.1991;114:845 -54
32. Gaillard J L, Merlino R, Pajot N, et al. Conventional & nonconventional modes of va administration to decontaminate the internal surface of the catheters colonized with coagulase--ve staph. J. Parenter. Enteral Nutr. 1990 ;14:593-97
33. Vander Meer JTM, Van Wijk W, Thompson J, Hans A. Valkenburgb, Marc F. Michelc. Awareness of need and actual use o f prophylaxis: Lack o f patient compliance in t he prevention of bacterial endocarditis. J Antimicrob Chemother 1992;29:187.
34. Etienne J, Eykyn S J. Increase in native valve endocarditis caused by CNS: An Anglo French clinical & microbiological study. Brtsh Hrt J. 1990; 64:381-4
35. Karchmer AW: Staphylococcal endocarditis. In Kaye D (ed). Infective Endocarditis. 2nd edition. Newyork, Raven Press, 1992, p 225.
36. Whitener C, Caputo GM, Weite Kamp MR, Karchmer AW. Endocarditis due to CNS: Microbiologic, epidemiologic and clinical considerations. Infect Dis Clin North Am. 1993; 7:81.
37. Ledingham David A JGG. Warrell. Concise oxford textbook of Medicine. In S.J Eykyn (ed). Staphylococci, Oxford University press; 2000 , p 1593-94.
38. van Wijngaerden E, Peeterma ns WE, van Lierde S, van Eldere J. Polyclonal Staph endocarditis. Clin. Infect. Dis. 19 97; 25:69 -71
39. Heilmann C, Peters G. Biology & pathogenicity of S.epidermidis. In: Fischetti VA, Novick RP, Ferretti JJ, et a l, eds. Gram-positive pathogens. Washington, DC: ASM, 2000, p 442-9
40. Huebner J, Goldmann DA. Coagulase -negative staphylococci: role as pathogens. Annu Rev Med 1999;50 :223-36
41. Nicolle LE, Hobsan SA, Harding GKM. Characterization of Coagulase negative staphylococci from urinary tract infections. J Clin Microbiol. 1983;17 :267-70.
42. Bannerman T. L., Rhoden DL, McAllister SK, Miller JM, Wilson LA. The source of coagulase-negative staphylococci in the Endophthalmitis Vitrectomy Study. A comparison of eyelid & intraocular isolates using pulsed-field gel electrophoresis. Arch. Ophthalmol. 19 97;115 :357-361.
43. Mozayeni R M, Lam S. Phlyctenular keratoconjunctivitis & marginal staphylococcal keratitis. In J. H. Krachmer, J. M. Mannis, E. J. Holland (ed), Cornea. Mosby-Year Book, St . Louis, Mo . 1996, p1392 -95.
44. O'Brien T. P, Maguire MG, Fink NE, Alfonso E, McDonnell P. The Bacterial Keratitis Study Research Group. Efficacy of ofloxacin versus cefazolin & tobramycin in the therapy f or bacterial keratitis. Arch. Ophthalmol. 1995; 113:1257-65
45. Hyndiuk RA, Eiferman RA, Caldwell DR, Rosenwasser GO, Santos CI, Katz HR, et al. Comparison of ciprofloxacin ophthalmic solution 0.3% to fortified tobramycin- cefazolin in treating bacterial corneal ulcers. Ophthalmo .199 6;103(11): 1854-62.
46. Snyder M E, Katz H. Ciprofloxacin-resistant bacterial keratitis. Am. J. Ophthalmol. 1992; 114:336-38
47. Degener J E, Heck M E O C, van Leeuwen WJ, Heemskerk C, Crielaard A, Joosten P, et al. Nosocomial infection by Staphylococcus haemolyticus & typing methods for epidemiological study. J. Clin. Microbiol.1994; 32:2260-65.
48. Stoll BJ, Gordon T, Korones SB, Shankaran S, Tyson JE, Bauer CR, et al. Late-onset sepsis in very low birth weight neonates: a report from the National Institute of Child Health and Human Development Neonatal Research Network. J Pediatr. 1996;129:63 -71.
49. Stoll BJ, Hansen N, Fanaroff AA, Wright LL, Carlo WA, Ehrenkranz RA, et al. Late-onset sepsis in very low birth weight neonates: the experience of the NICHD Neonatal Research Network. Pediatr. 2002;110:285-91.
50. Dear P. Textbook of Neonatology. In: J. M. Rennie, N. R. C. Robertson, editors. Infections in the new born, New York: Churchill Livingstone; 1999, p. 1109-1202.
51. Khadilkar V, Tudehope D, Fraser S. A prospective study of nosocomial infection in a neonatal intensive care unit. J. Pediatr. Child Health. 199 5;31 :387 -91.
52. Vermont C L, Hartwig N G, Fleer A , Peter de Man, Verbrugh H, John vanden Anker, et al. Persistence of Clones of Coagulase-Negative Staphylococci among Premature Neonates in Neonatal Intensive Care Units: Two-Center Study of Bacterial Genotyping & Patient Risk Factors: J Clin Microbio.1998; 36(9): 2485-90.
53. Huebner J, Pier GB, Maslow JN, Muller E, Shiro H, Parent M, et al. Endemic nosocomial transmission of S.epidermidis bacteremia isolates in a neonatal intensive care unit over 10 years: J Infect Dis. 199 4 ;169(3):526 -31
54. de Silva G D I, Kantzanou M, Justice A, R. C. Massey, A. R. Wilkinson, N. P. J. Day, et al. The ica Operon & Biofilm Production in Coagulase-Negative Staphylococci Associated with Carriage & Disease in a Neonatal Intensive Care Unit: J Clin Microbio .2002;40(2):382-88.
55. Jaffe R, Lane J.D, Albury S.V, Niemeyer D.M. Rapid extraction from & direct identification in clinical samples of methicillin-resistant staphylococci using the PCR. J. Clin. Microbiol.2000;38:3407-12.
56. Archer G. L. Alteration of cutaneous staphylococcal flora as a consequence of antimicrobial prophylaxis. Rev. Infect. Dis. 1991;13 (Suppl. 10):805-9.
57. Brakstad O.G, Maeland J.A. Mechanisms of methicillin resistance in staphylococci. APMIS. 1997;105: 264-76.
58. Antibiotic guide, John Hopkins Point of care,

http://hopkins-abxguide.org/, abxfeedback@hopkinsabxguide.org
59. Marshall S.A, Pfaller M.A, Jones R.N. Ability of the modified vitek card to detect coagulase-negative staphylococci with mecA & oxacillin resistant phenotypes. J. Clin. Microbiol.1999;37:2122-23.
60. Hyvarinen J, Huovinen P, Jarvinen H, Kotilainen P, Finnish Study Group for Antimicrobial Resistance (FiRe) (mukana Katila M-L). Multiresistance in Staphylococcus spp. blood culture isolates in Finland with special reference to t he distribution of the mecA gene among the Staphylococcus epidermidis isolates. APMIS 1995:103:885-9 1.
61. Alcaraz L E, Satorres S E, Lucero R M, Olga N, Puig de Centorbi. Species identification, slime production and oxacillin susceptibility in coagulase negative staphylococci isolated from nosocomial specimens. Braz. J Microbiol. 2003;34(1).

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