

Review Article

Coagulase Negative Staphylococci (CONS): A review

Abstract:

Coagulase-negative staphylococci (CoNS) has gain more importance as pathogenic organism in recent years as causative organism for infections in both human and animals. CONS are specially prevalent in immunocompromised patients, critically ill patients, patients having invasive medical devices. The incidence of CoNS varied across different geographic locations in humans and animals. Also, there is varying antibiotic resistance patterns observed in CoNS species, with high methicillin resistance and cross resistance against many antibiotics. *Staphylococcus epidermidis*, *Staphylococcus haemolyticus*, *Staphylococcus xylosus* are most commonly reported species in various studies. Various virulence factors in CONS are responsible for enhanced pathogenicity. Because of advancement in diagnostic techniques understanding of molecular mechanisms of CONS pathogenicity is possible. Recent advances in identification and typing methods, virulence screening methods will help to assess true pathogenic potential of CoNS species.

Comment [Office1]: Replace with especially

Comment [Office2]: are

Keywords: CONS, speciation, Infection

Introduction

Coagulase-negative Staphylococci (CONS) classified as mere contaminants, are becoming relevant clinically because of widespread antibiotic resistance, biofilm formation and increased use of medical devices. As there is marked species diversity in CONS, there is need for increased laboratory capacity for effective speciation.

Coagulase-negative Staphylococci (CONS) are normal flora of human skin and mucous membranes, they have previously been considered nonpathogenic or contaminant having little clinical significance.¹ But now they have been considered as significant potential pathogen responsible for hospital acquired infection because of widespread antibiotic resistance and increasing use of medical devices and occurs specially in immunocompromised patients and patients having indwelling devices.¹

Because of biofilm formation on medical devices, maximum of hospital acquired infections are caused by CONS. Biofilm formation also increases the resistance to antimicrobial agents and host defense mechanisms and because of that, it is very difficult to eradicate biofilm associated infections by conventional antibiotic treatment^{1,2}.

Comment [Office3]: majority

Milestones in CONS:

Table1. Milestones in CONS.

Year	Scientists	Milestones
1884	Rosenbach	First described CONS as <i>Staphylococcus albus</i> , an avirulent <i>Staphylococcus</i> ³ .
1958	Smith and coworkers	First reported pathogenicity of CONS in patients with septicemia ³ .
1965	Wilson and Stuart	Identified CONS in pure culture form ⁴ .
1962	Pereira	UTIs were caused by certain group of CONS which is now known as <i>S. saprophyticus</i> ⁵ .
1971	Pulverer and Pillich(Cologne, Germany)	Investigated pyogenic infections in Cologne, Germany and reported 10% infections were due to CONS and CONS were found in pure culture ⁶ .
1971	Holt	Reported that CONS were responsible for colonization of ventriculoatrial shunts followed by septicemia ⁷ .

Development in classification of Staphylococci have made clinicians more aware of various CONS species present in clinical specimens and as etiological agents. ⁸.

Table 2 shows various Staphylococcal species and subspecies.

Table2. staphylococcal species and subspecies (Lamers *et al* YEAR MISSING???)⁹

Table 1: staphylococcal species and subspecies (Lanners et al. YEAR MISSING...).								
Oxidase	Negative							
Novobiocin	Susceptible							
Coagulase	Negative		Positive –variable-negative				Negative	
Species group	Hyicus-Intermedius			Epidermidis-Aureus				
Cluster group	Muscae	Hyicus	Intermedius	Aureus	Epidermidis	Warneri	Haemolyticus	Lugdunensis
Species	S.muscae S.microti S.rostri	S.hyicus S.agnetis S.chromogenes S.felis	S.intermedius S. delphini S.lutrae S.pseudintermedius S.schleiferi sp. Schleiferi sp. coagulans	S.aureus ssp. Aureus ssp. Anaerobius S.simi ae	S.epidermidis S. capitis Sp. Capitis Sp. Urealyticus S.caprae S.saccharolyticus	S.warneri S.pasteuri	S.haemolyticus S.devriesei S.jettensis S.hominis Sp.hominis Sp.novobiocin S.petrasii Sp.croceilyticus S.petrasii	S.lugdunensis

Oxidase	Negative		Positive
Novobiocin	Susceptible		Resistant

in	Negative						
Coagulase	Negative						
Species group	Auricularis	Simulans	Saprophyticus				Sciuri
Cluster group	Auricularis	Simulans-Carnosus	Pettenkoffer-Massiliensis	Saprophyticus	Cohnii-Nepalensis	Arlettae-Kloosii	Sciuri
Species	S.auricularis	S.simulans S.carnosus sp. Carnosus sp utilis S.condimenti S.piscifermentans	S.pettenkoffer S.massiliensis	S.saprophyticus sp.saprophyticus sp. Bovis S.equorum sp.eqorum sp.linens S.gallinarum S.succinus sp. Succinus sp. Casei S.xylosus	S.cohnii sp.cohnii sp.urealyticus S.nepalensis	S.arlettae S.kloosii	S. Sciuri sp. Sciuri sp.carnaticus sp.rodentium S.fleurettii S.lentus S.stepanovicii S.vitulinus

Habitat:

CONS is a normal flora of skin and mucous membranes of humans and animals.^{10,11}

Table 3 shows colonizing areas of different CONS species.

Table 3. Colonizing areas of different CONS species.

CONS species	Colonizing areas
<i>S.epidermidis</i>	axillae, inguinal and perineal areas, anterior nares, conjunctiva, and toe webs ¹²
<i>S.hominis</i> <i>S.haemolyticus</i>	axillae and pubic region ¹² .
<i>S. capitis</i>	forehead and scalp following puberty ¹³ .
<i>S. lugdunensis</i>	Pelvic and perineum regions, lower extremities, axillae ¹⁴ .
<i>S. saprophyticus subsp. saprophyticus</i>	Rectum and genitourinary tract ¹² .
<i>S. auricularis</i>	Human external ear ¹⁵ .

Transmission:

Maximum CONS infections are hospital-acquired or health-care related infections as they have the ability to survive in ICU, on medical devices and medical equipment's for months^{16,17,18}. Some clones are probably endemic in the hospital environment.^{18 19} The *mecA* gene carriage in these clusters is usually very high, which suggests that antibiotic resistance is one of the major selective forces²⁰⁻²³

Emergence and spread of CONS in hospitals is dependent on following factors:

- Duration of hospital stay (especially ICU stay),
- Antibiotic treatment period
- antibiotic pressure in the environment
- hygiene standards¹⁶.

Hand hygiene precautions is extremely important for preventing nosocomial colonization and infections.

Risk factors for CONS infections:

Risk factors for CONS infections includes medical conditions such as ²⁴

- immune suppression
- premature birth
- neutropenia
- dependence of renal dialysis
- malignancy
- cardiothoracic surgery
- long term hospitalization

Microbiological Profile of CONS:

Morphology:

CONS are gram-positive, non-motile, non-spore-forming cocci. They are usually arranged in irregular (grape-like) clusters or singly, in short chains (three or four cells), in pairs or tetrads.

Classical approach for separation of CONS from coagulase positive Staphylococci:

Coagulase can contribute to pathogenicity by inhibiting the bactericidal activity of normal serum and by inhibiting phagocytosis through deposition of fibrin on the bacterial cell walls. In the laboratory, two types of coagulase tests are used such as slide test and tube test. Table 2 shows all the coagulase positive and coagulase negative Staphylococci species.

Grouping of CONS by novobiocin testing:

For CONS isolates which have been recovered from urinary tract specimens, novobiocin resistance is used to distinguish the intrinsically resistant *S. saprophyticus* subsp. *saprophyticus* from other clinically important CONS, using a 5 ug novobiocin disc on Mueller-Hinton agar²⁵.

Novobiocin resistant species are *S. saprophyticus* subsp. *Saprophyticus*, *S. vitulinu*, *S. xylosus*

S. hominis subsp. *Novobiosepticus*, *S. sciuri* subsp. *Sciuri*, *S. cohinii*, *S. cohinii* subsp. *urealyticus*.

CONS species and subspecies:

Currently at present, there are 32 recognized species and eight subspecies present in the genus *Staphylococcus* (**Table 2**) and about one-half of these are indigenous to humans.

EX. *S. epidermidis* *S. capitis* *S. saccharolyticus* *S. warneri* *S. hominis* *S. lugdunensis* *S. auricularis* *S. cohnii* *S. saprophyticus* *S. xylosus* *S. caprae* *S. haemolyticus*

Table 4 shows various CONS species causing human infections.

Table 6. CONS species causing human infections ²⁵.

CONS species or subspecies	Site or source of infection (humans)	Clinical association on frequency	
		Device associated infections	Other infections
<i>S.epidermidis</i>	Skin (axillae, head, arms, legs) and mucous membranes of the nasopharynx	++++	Blood stream infections in neonates (++++)
<i>S.auricularis</i>	External auditory canal	-	Blood stream infections in preterm infant
<i>S.capitis</i> subspecies <i>capitis</i>	mainly scalp, arms,	+	Blood stream infections in neonates (+)
<i>S. capitis</i> subsp. <i>urealyticus</i>	skin of (heads,ears and foreheads)	+	Blood stream infections in neonates (++)
<i>S. caprae</i>	Skin, anterior nares	+	Urinary tract infection(+)
<i>S. cohnii</i> subsp. <i>cohnii</i>	Skin	++	Blood stream infections in burn patient(+)
<i>S. cohnii</i> subsp. <i>urealyticus</i>	Skin		Blood stream infections (+)
<i>S. haemolyticus</i>	Skin ,(legs and arms)	+++	Blood stream infections neonates(+++)
<i>S. hominis</i> subsp. <i>hominis</i>	Skin of axillae, arms, legs, pubic, inguinal regions)	++	Blood stream infections(+)
<i>S. lugdunensis</i>	Skin of lower abdomen and extremities)	++	wound infection (++)Native valve infectious

			endocarditis,(++)SSI (++)
<i>S. saprophyticus</i> subsp.saprophyticus	Skin	+	Urinary tract infections (++++) Blood stream infections (+) , Native valve infectious endocarditis(+)
<i>S. schleiferi</i> subsp.schleiferi	Skin (preaxillary)	+	Blood stream infections (+) wound Infection(+)
<i>S. sciuri</i> subsp. carnaticus	Skin	-	Blood stream infections (?)
<i>S. sciuri</i> subsp. rodentium	Skin	-	Blood stream infections (?)
<i>S. sciuri</i> subsp. sciuri	Skin	+	wound infection (?) Blood stream infections (?)
<i>S. simulans</i>	Skin (legs, arms, and heads of children)	+	-
<i>S. warneri</i>	Skin (mainly nares, head, legs, and arms)	++	Septic arthritis(+)
<i>S. xylosum</i>	Skin (rare)	+	-

Abbreviations: ?, questionable or unconfirmed; +, single cases; ++, occasional detection; +++, frequent detection; ++++ most common origin.

Virulence factor in CONS:

CONS are seldom life-threatening except in immunocompromised patients as CONS do not produce aggressive virulence factors.¹

Capsule:

Among CONS, capsule formation is frequent and they possess increased virulence compared to non-encapsulated variant strains. Slime may contain capsular polysaccharides, proteins and cell wall components. The capsule confers resistance to phagocytosis²⁶.

Slime: Glycocalyx is considered a slime layer when glycoprotein molecules are loosely attached with the cell wall. Slime material and biofilm formation has important role in colonization of uroepithelium and medical device- associated infections²⁷. Slime has also been shown to inhibit the cell mediated immune response *in vitro*.

Biofilm:

Biofilm structures comprises mainly bacterial cells and an extracellular polymeric substance (EPS) provided by the polysaccharide intercellular adhesion (PIA). PIA synthesis is associated with intercellular adhesion operon (ica ADBC) ²⁸.

Biofilm provides

- protective environment to microorganisms
- quorum sensing (the exchange of genetic material between cells and intercellular communication)²⁹
- the micro-organisms becomes more resistant to antibiotics and to host defense mechanisms.

.Cytolytic toxins:

Delta-toxin (PSM is produced by *S. epidermidis*. It forms pores in the cell membrane which leads to erythrocytes and other mammalian cells lysis. ²⁵.

Production of Lantibiotics:

antibiotic-like peptides produced by commensal staphylococci are called lantibiotics and belongs to the class of cationic antimicrobial peptides (CAMPs) and are active against gram-positive bacteria. Lantibiotics production has role in bacterial interference on skin and mucous membranes. Type A lantibiotics induce pores in the cytoplasmic membrane. Lantibiotics produced by *S. epidermidis* are epidermin, Pep5, epilancin K7, epidermicin NI01, and epicidin 280. Other species such as *S. gallinarum* (gallidermin), *S. hominis* (hominicin), and *S. warneri* (nukacin ISK-1) also show lantibiotic production.²⁵.

Siderophore:

Microorganisms produce low molecular weight (<1000D) chelating compounds called siderophore in their iron especially in free form. Siderophores are helpful to overcome host's non-specific defense mechanisms and thus helpful in survival within the host, ³⁰.

Meiwees et al. ³¹ has detected two iron binding compounds, staphyloferrin A and B which were highly hydrophilic and anionic.

Extracellular Enzymes:

CONS produces variety of enzymes and extracellular proteins such as proteases, lipases, phospholipases, esterase's, protein A, and fatty acid modifying enzymes. Protease are responsible for proteolytic inactivation of antibodies, platelet microbicidal proteins, and destruction of tissue protein which leads to increased invasiveness. *S. epidermidis* has two lipase genes involved in skin colonization ³².

Exopolymers:

Polysaccharide intercellular adhesin (PIA) and poly gamma-glutamate (PGA)s are produced by *S. epidermidis*.

Functions of PGA:

- protecting against neutrophil phagocytosis and antimicrobial peptides.
- important for survival in biofilm and as a commensal on the skin,

- during high salt concentrations it promotes growth by increase osmo-tolerance.

PIA has similar functions as PGA and also protects against complement deposition and immunoglobulins³³.

Table 5 shows various virulence factors of *S. epidermidis*.

Table 5. Important virulence factors of *S. epidermidis*³³.

Virulence factor	Gene	Function
Intercellular aggregation		
PIA (PNAG)	icaA,icaD,icaB, and icaC	Polysaccharide intercellular adhesion
Aap Bhp	Aap ,Bhp	Protein intercellular adhesion
Teichoic acids	Multiple biosynthetic genes	Components of the biofilm matrix
Protective exopolymers		
PIA	icaA,icaD,icaB, and icaC	Protects from IgG, AMPs, phagocytosis
PGA	capA,capB,capC and capD	Protects from AMPs and phagocytosis
Resistance to AMPs		
Sep A protease	sepA	Involved in AMP degradation
Aps system	apsR, apsS, and apsX	senses AMPs and regulates AMP resistance mechanism
Toxins		
PSMs	psma,psmd,psme, hld	Pro-inflammatory cytolytins
Exoenzymes		
Glutamylendopeptidase GluSE and serine proteases SspA and Esp	sspA	Degrades fibrinogen and complement factor C5
Cysteine proteases SspB and Ecp	sspB	Possibly responsible for tissue damage
Other factors		
Staphyloferrins A and B	Sfna locus	Siderophores (iron acquisition)
SitA, SitB and SitC	sitA, sitB and sitC	Involved in iron uptake

Figure 1 shows scheme for identification of human CONs

Table 6 shows Various biochemical characteristics of CONS

Table 7. Biochemical characteristics of coagulase negative Staphylococci ³⁴

Species	Coagulase test									Carbohydrate fermentation test							
	Slide	Tube	NV	Pol-B	PYR	Nit	VP	Ure	ODC	Glu	Mal	Su	La	Man	Mo	Xy	Tre
<i>S. epidermidis</i>	–	–	S	R	–	+	+	+	V	+	+	+	V	–	+	–	–
<i>S. saprophyticus</i> subsp saprophyticus	–	–	R	S	–	–	+	+	–	+	+	+	V	v	–	–	+
<i>S. haemolyticus</i>	–	–	S	S	+	–	+	–	–	+	+	+	V	V	–	–	+
<i>S. hominis</i> subsp hominis	–	–	S	S	–	V	V	+	–	+	+	+	V	–	–	–	V
<i>S. hominis</i> subsp novobioceticus	–	–	R	NA	–	V	V	+	–	+	+	+	V	–	–	–	–
<i>S. lugdunensis</i>	+	–	S	S/R	+	+	+	V	+	+	+	+	+	–	+	–	+
<i>S. schleiferi</i> subsp schleiferi	+	V	S	S	+	+	+	–	–	+	–	–	–	–	+	–	V
<i>S. schleiferi</i> subsp coagulans	V	+	S	NA	NA	+	+	+	NA	+	–	v	V	V	+	–	–
<i>S. warneri</i>	–	–	S	S	–	V	+	+	–	+	+	+	v	V	–	–	+
<i>S. xylosus</i>	–	–	R	S	V	V	V	+	–	+	+	+	v	+	+	+	+
<i>S.intermedius</i>			S	S	+	+	–	+	–	+	v	+	V	V	+	–	+
<i>S.hyicus</i>	–	V	S	R	–	+	–	V	–	+	–	+	+	–	+	–	+
<i>S.cohnii</i> subsp. Cohnii	–	–	R	S	–	–	V	–	–	+	V	–	–	V	V	–	+

Abbreviations: NV-Novobiocin, Pol-B- Polymyxin-B, Nit- Nitrate reduction test, Ure-Urease Production test, ODC- Ornithine Decarboxylase test, Glu-Glucose, Mal-Maltose, Su-Sucrose, La- Lactose, Man-Mannitol, Mo-Mannose, Xy-Xylose, Tre-Trehalose. V-Variable, R-Resistant, S-Susceptible, + Positive,- Negative

Molecular methods:

Genotypic methods have higher discriminatory power and are less laborious.^{35,36}

Disadvantages:

1. Costly, expensive

2. Time consuming

Commercial identification systems:

With these commercial kits, identification of human CONS species can be possible with accuracy of 70->90%. For organism identification these kits use adaptations of standard bacteriologic identification tests, chromogenic enzyme substrate tests and modified carbohydrate fermentation tests.

Different systems available for identification of CONS are ³⁴

1. API Staph
2. BD Phoenix system
3. BD Phoenix ID-13 system
4. VITEK 2 ID-GP system
5. ID 32 STAPH system
6. Rapidec STAPH
7. API Staph- IDENT
8. MICROSCAN RAPID POS COMBO PANEL
9. STAF- SISTEM 18-R
10. STAPH-ZYM
11. MICROBIAL IDENTIFICATION SYSTEM

As there is addition of more discriminating tests and availability of growing data bases, the reliability of these commercial systems will continue to increase ³⁴.

REFERENCES:

1. Otto, M. (2004). Virulence factors of the Coagulase negative staphylococci. *Front. Biosci.*9: 841-863.
2. Rupp, M.E. and Archer, G.L.(1994). Coagulase negative Staphylococci: pathogens associated with medical progress. *Clin. Infect. Dis.*19:231-245.
3. Rosenbach FJ. 1884. *Micro-Organismen bei den Wund-Infections-Krankheiten des Menschen*. J F Bergmann, Wiesbaden, Germany.
4. Wilson, T. S., and R. D. Stuart. 1965. Staphylococcus albus in wound infection and in septicemia. *Can. Med. Assoc. J.* 93:8-16.
5. Pereira, A. T. 1962. Coagulase-negative strains of Staphylococcus possessing antigen 51 as agents of urinary infection. *J. Clin. Pathol.* 15:252-259.
6. Pulverer, G., and J. Pillich. 1971. Pathogenic significance of coagulase-negative staphylococci, p. 91-96. In M. Finland, W. Marget, and K. Bartmann (ed.), *Bacterial infections: changes in their causative agents; trends and possible basis*. Springer- Verlag, New York.
7. Holt, R. J. 1971. The colonization of ventriculoatrial shunts by coagulase-negative staphylococci, p. 81-87. In M. Finland, W. Marget, and K. Bartmann (ed.), *Bacterial infections: changes in their causative agents, trends and possible basis*. Springer- Verlag, Stuttgart, Germany.

8. Götz F., Bannerman T., Schleifer KH. (2006) The Genera *Staphylococcus* and *Micrococcus*. In: Dworkin M., Falkow S., Rosenberg E., Schleifer KH., Stackebrandt E. (eds) The Prokaryotes. Springer, New York, NY.
9. Lamers RP, Muthukrishnan G, Castoe TA, Tafur S, Cole AM, Parkinson CL. 2012. Phylogenetic relationships among *Staphylococcus* species and refinement of cluster groups based on multilocus data. *BMC Evol. Biol.* 12:171.
10. Grice, E. A., H. H. Kong, S. Conlan, et al. (2009). Topographical and temporal diversity of the human skin microbiome. *Science* 324(5931): 1190-1192.
11. Costello EK, Lauber CL, Hamady M, Fierer N, Gordon JI, Knight R. 2009. Bacterial community variation in human body habitats across space and time. *Science* 326:1694–1697.
12. Schleifer KH, Kloos WE. 1975. Isolation and characterization of staphylococci from human skin. I. Amended descriptions of *Staphylococcus epidermidis* and *Staphylococcus saprophyticus* and descriptions of three new species: *Staphylococcus cohnii*, *Staphylococcus haemolyticus*, and *Staphylococcus xylosus*. *Int. J. Syst. Bacteriol.* 25:50–61.
13. Kloos WE, Schleifer KH. 1975. Isolation and characterization of staphylococci from human skin. II. Description of four new species: *Staphylococcus warneri*, *Staphylococcus capitis*, *Staphylococcus hominis*, and *Staphylococcus simulans*. *Int. J. Syst. Bacteriol.* 25:62–79.
14. Bieber L, Kahlmeter G. 2010. *Staphylococcus lugdunensis* in several niches of the normal skin flora. *Clin. Microbiol. Infect.* 16:385–388.
15. Kloos WE, Schleifer KH. 1983. *Staphylococcus auricularis* sp. nov.: an inhabitant of the human external ear. *Int. J. Syst. Bacteriol.* 33:9–14.
16. Widerström, M., Monsen, T., Karlsson C., Wiström, J., 2006. Molecular epidemiology of methicillin-resistant coagulase-negative staphylococci in a Swedish county hospital: evidence of intra and interhospital clonal spread. *J. Hosp. Infect.* 64, 177-183.
17. Kloos, W. E. and Bannerman, T.L. (1994). Update on clinical significance of coagulase negative staphylococci. *Clin. Microbiol. Rev.* 7:117-40.
18. Neely, A.N., Maley, M.P., 2000. Survival of Enterococci and Staphylococci on hospital fabrics and plastic. *J. Clin. Microbiol.* 38, 724–726.
19. Agvald-Ohman, C., Lund, B., Edlund, C., 2004. Multiresistant coagulase-negative staphylococci disseminate frequently between intubated patients in a multidisciplinary intensive care unit. *Crit. Care.* 8, R42-R47.
20. Krediet, T.G., Mascini, E.M., van Rooij, E., Vlooswijk, J., Paauw, A., Gerards, L.J., Fleer, A., 2004. Molecular epidemiology of coagulase-negative staphylococci causing sepsis in a neonatal intensive care unit over an 11-year period. *J. Clin. Microbiol.* 42, 992-995.
21. Kozitskaya, S., Olson, M.E., Fey, P.D., Witte, W., Ohlsen, K., Ziebuhr, W., 2005. Clonal analysis of *Staphylococcus epidermidis* isolates carrying or lacking

- biofilm-mediating genes by multilocus sequence typing. *J. Clin. Microbiol.* 43, 4751–475.
22. Hira, V., Sluijter, M., Estevão, S., Horst-Kreft, D., Ott, A., de Groot, R., Hermans, P.W., Kornelisse, R.F., 2007. Clinical and molecular epidemiologic characteristics of coagulase-negative staphylococcal bloodstream infections in intensive care neonates. *Pediatr. Infect. Dis. J.* 26, 607-612.
 23. Nouwen, J.L., van Belkum, A., de Marie, S., Sluijs, J., Wielenga, J.J., Kluytmans, J.A., Verbrugh, H.A., 1998. Clonal expansion of *Staphylococcus epidermidis* strains causing Hickman catheter-related infections in a hemato-oncologic department. *J. Clin. Microbiol.* 36, 2696-2702.
 24. Bozkurt H, Kurtoglu MG, Bayram Y, Keşli R, Berktaş M. Correlation of slime production investigated via three different methods in coagulase-negative staphylococci with crystal violet reaction and antimicrobial resistance. *The Journal of International Medical Research.* 2009;37:121-128.
 25. Becker K, Heilmann C, Peters G. Coagulase-Negative Staphylococci. *Clinical Microbiology Reviews.* 2014; 27(4):870-926.
 26. Hancock, C, (1989). Encapsulation of Coagulase negative staphylococci. *Zentralbi, Bakteri.* 272(1);11-18.
 27. Bayston, R and Rodgers, J.(1990). Production of extracellular slime by *Staphylococcus epidermidis* during stationary phase of growth. *J. Clin. Pathol.* 43:866-870.
 28. Heilmann, C., Thumm, G., Chhatwal, G. S., Hartleib, J., Uekotter, A., Peters G. (2003) Identification and Characterization of a novel autolysin (Aac) with adhesive proportion from *Staphylococcus epidermidis*. *Microbiology.* 149:2769-2778.
 29. Rodney, M.D and Costerton, J.W (2002). Biofilms: survival mechanism of clinically relevant microorganisms. *Clin. Microbiol. Rev.* 15(2):167-193.
 30. Bullen, J.J. and Griffiths, E. (1999). Iron binding proteins and host defense in Iron and infections, In: Bullen, J.J and Griffiths, E. (eds). *Molecular, Physiological and Clinical Aspects*, John Wiley and sons, Chichester, UK. Pp-327-368.
 31. Meiwees, J., Fiedler, H.P., Haag, H., Zahner, H., Koneschny, R., Jung, G. (1990). Isolation and characterization of staphyloferrin a, a compound with siderophore activity from *Staphylococcus hyicus*. *FEMS, Microbiol, Lett.* 67, 201-206.
 32. Simons, J.W., Vankampen, M.D., Riel, S., Gotz, F., Egmond, M.R., Verheij, H.M. (1998). Cloning, purification and characterization of the lipase from *Staphylococcus epidermidis*, comparison of the substrate selectivity with those of other microbial lipases. *Eur. J. Biochem.* 253; 675-683.
 33. Otto, M. (2009). *Staphylococcus epidermidis*-the accidental pathogen. *Nat. Rev. Microbiol.* 7(8) ;555-567.
 34. Washington CW Jr, Stephen DA, William MJ et al. Koneman's color Atlas and Textbook of diagnostic Microbiology, in Gram positive cocci. Ch 12; 6th ed, Lippincott Williams and Williams, USA, 2006; p623-71.

35. Heikens, E., Fleer, A., Paauw, A., Florijn, A.C., Fluit, A., 2005. Comparison of genotypic and phenotypic methods for species-level identification of clinical isolates of coagulase-negative staphylococci. *J. Clin. Microbiol.* 43, 2286-2290.
36. Layer, F., Ghebremedhin, B., Moder, K., König, W., König, B., 2006. Comparative study using various methods for identification of *Staphylococcus* species in clinical specimens. *J. Clin. Microbiol.* 44, 2824-2830.

UNDER PEER REVIEW