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Coagulase Negative Staphylococci (CoNS): A Review

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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Review Article

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ABSTRACT

Coagulase-negative staphylococcus (CoNS) has gained more importance as pathogenic organism for infections in both human and animals. CoNS are especially 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 are 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 the 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.
This review focuses on various CoNS species, their identification and virulence factors and clinical importance.

Keywords: CoNS species; CoNS identification.

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1. INTRODUCTION

Coagulase-negative Staphylococci (CoNS) classified as mere contaminants, are becoming clinically relevant because of widespread of antibiotic resistance, biofilm formation and increased use of medical devices such as Central venous line, urinary catheter, Prosthetic valves etc. 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.

Because of bioflim formation on medical devices, majority 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 [2-4].

1.1 Milestones in CoNS

Table 1 shows important Milestones about CoNS.

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 *Staphylococcus species and subspecies.*

1.2 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.

1.3 Transmission

Maximum CoNS infections are hospital-acquired or health-care related infections as they have the ability to survive in ICU(Intensive care unit), on medical devices and equipments 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 forces [20-23].

Emergence and spread of CoNS in hospitals is dependent on duration of hospital stay (especially ICU stay), Antibiotic treatment period,antibiotic pressure in the environment and hygiene standards [16]. Hand hygiene precautions is extremely important for preventing nosocomial colonization and infections.

1.4 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 and long term hospitalization.

2. MICROBIOLOGICAL PROFILE OF CONS

2.1 Morphology

CoNS are gram-positive, nonmotile, 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.

2.1.1 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.

2.1.2 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 agar [25].

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.

2.1.3 CoNS species and subspecies

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.

2.2 Virulence Factor in CoNS

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

2.2.1 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 phagocytosis [26].

2.2.2 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 infections [27]. Slime has also been shown to inhibit the cell mediated immune response in vitro.

2.2.3 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 and responsible for quorum sensing(the exchange of genetic material between cells and intercellular communication) [29]. Micro-organisms becomes more resistant to antibiotics and to host defense mechanisms due to biofilm.

2.2.4 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].

2.3 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].

2.3.1 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].

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

2.3.2 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].

2.3.3 Exopolymers

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

Table 1. Milestones in CoNS

Year	Scientists	Milestones
1884	Rosenbach	First described CoNS as Staphylococcus albus, an avirulent Staphylococcus [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 S. saprophyticus[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].

Table 2. Staphylococcus species and subspecies [9]

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.simiae	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.novobiosepticus S.petrasii Sp.croceilyticus Sp.petrasii	S.lugdunensis

Continued

Oxidase	**Negative**						**Positive**
Novobiocin	**Susceptible**				**Resistant**		
Coagulase	**Negative**						
Species group	**Auricularis**	**Simulans**	**Saprophyticus**				**Sciuri**
Cluster group	Auricularis	Simulans-Carnosus	Pettenkoferi-Massiliensis	Saprophyticus	Cohnii-Nepalensis	Arlettae-Kloosii	Sciuri
Species	S.auricularis	S.simulans S.carnosus sp. Carnosus sp utilis S.condimenti S.piscifermentans	S.pettenkoferi 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

Table 3. Colonizing areas of different CoNS species

CONS species	**Colonizing areas**
S.epidermidis	Axilla, inguinal and perineal areas, anterior nares, conjunctiva, and toe webs [12].
S. hominis S. haemolyticus	axilla and pubic region [12].
S. capitis	Fore-head and scalp following puberty [13].
S. lugdunensis	Pelvic and perineum regions, lower extremities, axillae [14].
S. saprophyticus subsp. saprophyticus	Rectum and genitourinary tract [12]
S. auricularis	Human external ear [15].

Table 4. 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
S.epidermidis	Skin (axillae, head, arms, legs) and mucous membranes of the nasopharynx	++++	Blood stream infections in neonates (++++)
S.auricularis	External auditory canal	-	Blood stream infections in preterm infant
S.capitis subspecies capitis	mainly scalp, arms,	+	Blood stream infections in neonates (+)
S. capitis subsp. Urealyticus	skin of (heads,ears and foreheads)	+	Blood stream infections in neonates (++)
S. caprae	Skin, anterior nares	+	Urinary tract infection(+)
S. cohnii subsp. Cohnii	Skin	++	Blood stream infections in burn patient(+)
S. cohnii subsp. Urealyticus	Skin		Blood stream infections (+)
S.haemolyticus	Skin ,(legs and arms)	+++	Blood stream infections neonates(+++)
S. hominis subsp. Hominis	Skin of axillae, arms, legs, pubic, inguinal regions)	++	Blood stream infections(+)
S.lugdunensis	Skin of lower abdomen and extremities)	++	wound infection (++)Native valve infectious endocarditis,(++)SSI (++)
S. saprophyticus subsp. saprophyticus	Skin	+	Urinary tract infections(++++) Blood stream infections (+) , Native valve infectious endocarditis(+)
S. schleiferi subsp.schleiferi	Skin (preaxillary)	+	Blood stream infections(+) ,wound Infection(+)
S. sciuri subsp. Carnaticus	Skin	-	Blood stream infections (?)
S. sciuri subsp. Rodentium	Skin	-	Blood stream infections (?)
S. sciuri subsp. Sciuri	Skin	+	Wound infection (?) Blood stream infections (?)
S. simulans	Skin (legs, arms, and heads of children)	+	-
S. warneri	Skin (mainly nares, head, legs, and arms)	++	Septic arthritis(+)
S. xylosus	Skin (rare)	+	-

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

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		
SepA 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 cytolysins
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

Table 6. Biochemical characteristics of Coagulase Negative Staphylococci [34]

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

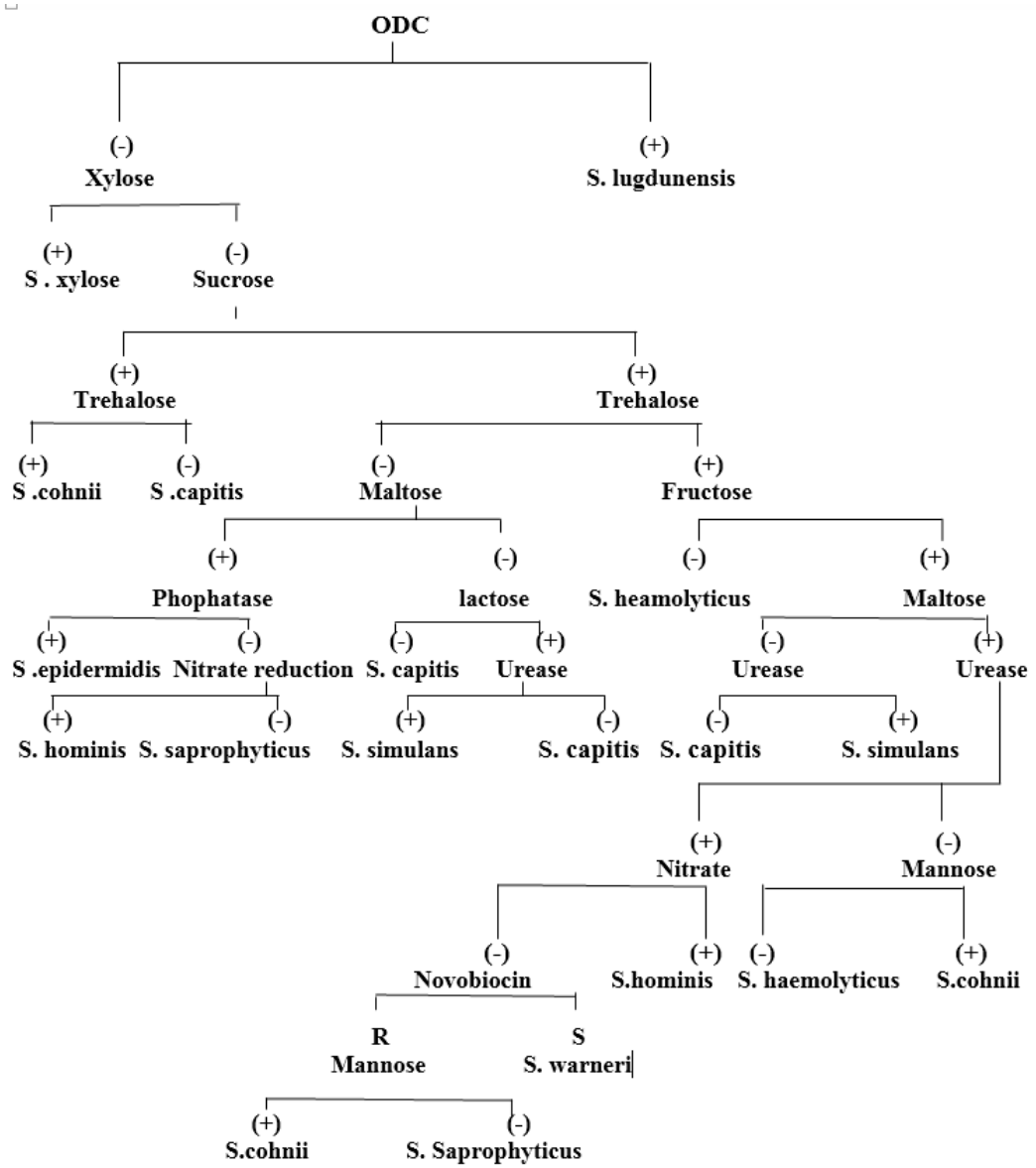

Fig. 1. Flow chart of dichotomous key for identification of common human CoNS [8]

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 osmotolerance.

PIA has similar functions as PGA and also protects against complement deposition and immunoglobulins [33].

Table 5 shows various virulence factors of S. epidermidis.

Flow chart Fig 1 shows scheme for identification of human CoNS.

Table 6 shows various biochemical characteristics of CoNS.

2.4 Molecular Methods

Genotypic methods have higher discriminatory power and are less laborious [35,36]

2.4.1 Disadvantages

1. Costly
2. Time Consuming
3. Requires experienced and skilled personnel

4. Facilities not available in all areas
5. High stringency necessary to avoid false positive results

2.4.2 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].

3. CONCLUSION

CoNS is already causing a significant level of infection and morbidity. It won't take long before it starts having huge impact on the immuno-compromised patients, with the increasing use of foreign materials like prosthetic valves, catheters, central lines and other medical advances. Additional factors like increasing antimicrobial resistance and virulence in the species might limit its treatment. Thus it's necessary to study CoNS at species level to understand their role as reservoir of virulence and resistance genes. Also it will help develop colonization preventing materials for various uses.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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