STAPHYLOCOCCI

GENERAL FEATURES

Staphylococci are gram-positive cocci that naturally reside in the normal human flora. However under the certain circumstances they may become pathogenic. *S. aureus*, a coagulase positive staphylococcus species, is the most common bacterial agent of purulent (pyogenic) infections in humans. These infections range from trivial localised skin infections to infections with fatal outcomes (e.g. septicemia). Food poisoning, another important outcome of staphylococcal infections, is caused by a heatstable enterotoxin. Staphylococci are also important as they can rapidly develop resistance to a variety of antibiotics. This is seen in nosocomial strains.

VIRULENCE FACTORS AND PATHOGENESIS

Virulence factors are genetic, biochemical, or structural features that enable an organism to cause disease.

Cell wall component: The capsule inhibits phagocytosis. Peptidoglycan of the cell wall has endotoxin-like activity. Protein A binds non-specifically to Fc-receptors of IgG and thereby prevents antibody mediated clearance.

Enzymes & toxins: Coagulase binds to prothrombin and initiates polymerization of fibrin which deposits on the surface of the microbe preventing ingestion by phagocytes.

Septic thrombi caused by *Staphylococcus aureus* usually **develop when infection and clot formation happen together.** The key idea: something allows bacteria into the bloodstream and creates a surface where a clot can form. Here are the main causes and risk factors: **1. Bloodstream infection (bacteremia) -** Anything that introduces *S. aureus* into the blood can start the process: Skin infections (abscesses, cellulitis), Infected wounds, IV drug use, Surgical site infections. Once in the blood, the bacteria can attach to vessel walls and trigger clotting. **2. Intravascular devices, 3. Infective endokarditis, 4. Venous stasis or vessel injury, 5. Local infections spreading to veins**

Cytotoxins (e.g. hemolysins) □, β, γ, δ attack mammalian cell membranes causing lysis. The superantigen toxic shock syndrome toxin 1 non-specifically induces T lymphocytes to release large amounts of cytokines which causes hypovolemic shock and multiorgan failure. Panton-Valentine leukocidin (PVL) is a bicomponent pore-forming toxin composed of two proteins, LukS-PV and LukF-PV, which assemble into pores in the membranes of immune cells such as neutrophils, monocytes, and macrophages. This leads to cell lysis and contributes to inflammation and tissue damage.

Enterotoxins are the cause of food poisoning.

Exfoliatins cause the skin desquamation of staphylococcal scalded skin syndrome by dissolving the desmosomal
connections between cells of the epidermis.

INFECTIONS

1. Localized skin infections: e.g. folliculitis (inflammation of hair follicles, small superficial
abscesses), furuncles (boils, subcutaneous abscesses), carbuncles (deep multiloculated
abscesses), impetigo (crustous skin lesions).

2. Deep localized infections: e.g. septic arthritis (often disseminated from a superficial
infection), osteomyelitis.

3. Bacteremia and acute endocarditis (AE): *S. aureus* bacteremia occurs in most patients
after the appearance innocuous appearing skin infections. 50% of cases appear in hospital
environments either after surgery or from contaminated catheters.
AE is a serious disease with a high mortality that is associated with intravenous drug use.

INFECTIONS

4. Pneumonia and empyema: Aspiration pneumonia is caused by aspiration of contaminated air. It primarily affects children and the elderly. Hematogenous pneumonia
can develop following bacteremia or endocarditis. Necrotizing pneumonia is caused by
strains that produce leukcidin. Empyema occurs in 10% of patients with pneumonia. The
drainage of the purulent material is often difficult because of pulmonary consolidation.

5. Toxinoses: Gastroenteritis is caused by a toxin preformed in improperly prepared contaminated food after few hours of incubation time. Toxic Shock Syndrome (TSS), a
possible consequence, is a type of hypovolemic shock.

6. Coagulase negative staphylococci (CNS) as agents of catheter and prosthetic joint infections and infections of urinary tract: CNS can produce a slime that binds the

TREATMENT, PREVENTION & CONTROL

Staphylococci are ubiquitous human bacteria. Prevention of staphylococcal infections includes barrier safety measures and disinfections. Trivial skin infections can be treated by antiseptics and/or local antibiotics. Serious skin or deeply localized infections (e.g. carbuncule) on the other hand have to be surgically drained and aggressively treated by systemic antibiotics. Most strains (70-90%) of *S. aureus* are resistant to penicillin G so an isoxazollyl penicillin (e.g. oxacillin) is the drug of choice. Infections caused by resistant strains to the latter antibiotics (e. g. MRSA) are
treated by glycopeptides (e. g. vancomycin).

LABORATORY DIAGNOSIS

Specimen collection includes swabs, pus, blood aspirations, cerebrospinal fluid and other
clinical material depending upon the localization of the infection.

a) Microscopy: Staphylococci are seen as regular gram-positive cocci arranged in

grapelike clusters (fig. 1).

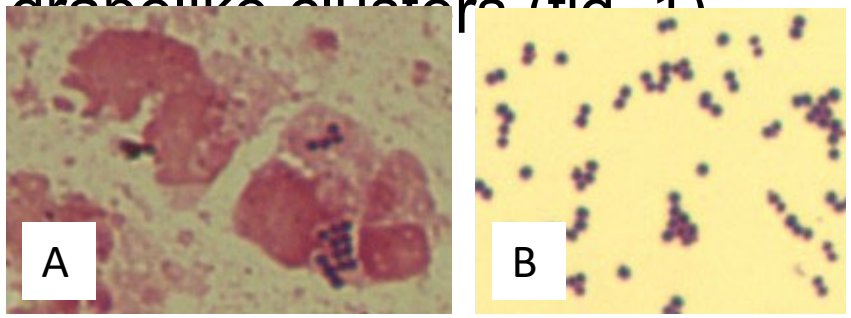

Figure 1. Staphylococci and activated PMNs in the sputum sample of a patient suffering with staphylococcal pneumonia. B. Regular gram-positive cocci arranged in clusters from a staphylococcal culture.

b) Culture: Staphylococci grow rapidly (overnight) on general and enriched culture media as white or yellowish smooth colonies (fig. 2). Hemolysis on blood agar are caused by hemolysins (e.g. toxin – a cytotoxin). If a competitive and possibly overgrowing flora is suspected selective (7,5% NaCl) or diagnostic

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specific colour on this agar).

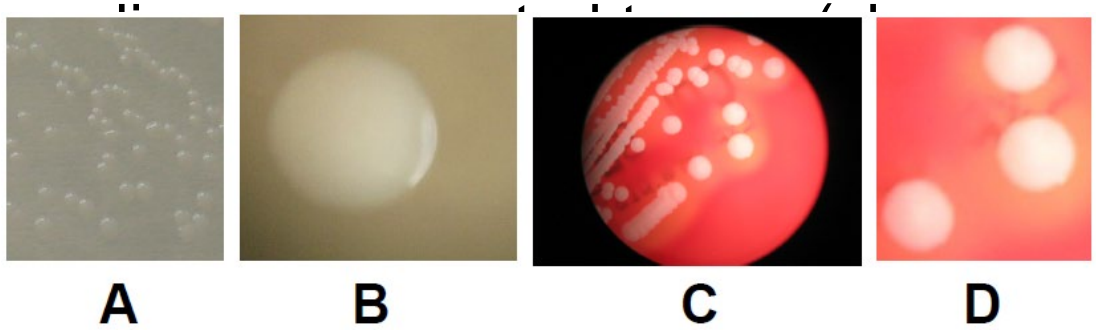

Figure 2. Colonies of *Staphylococcus aureus* on a nutrient agar (A), close up (B), enrichment media – blood agar (C), close up (D)

c**) Phenotypical identification**: Detection of specific biological properties of staphylococci (microscopy, bacterial colonies, enzyme detection) (see also chapter 6 – Identification).

Screening tests (preliminary identification)(fig. 3): detection of catalase (catalyze the

decomposition of H2O2 to water and oxygen). Detection of coagulase (convert fibrinogen to f

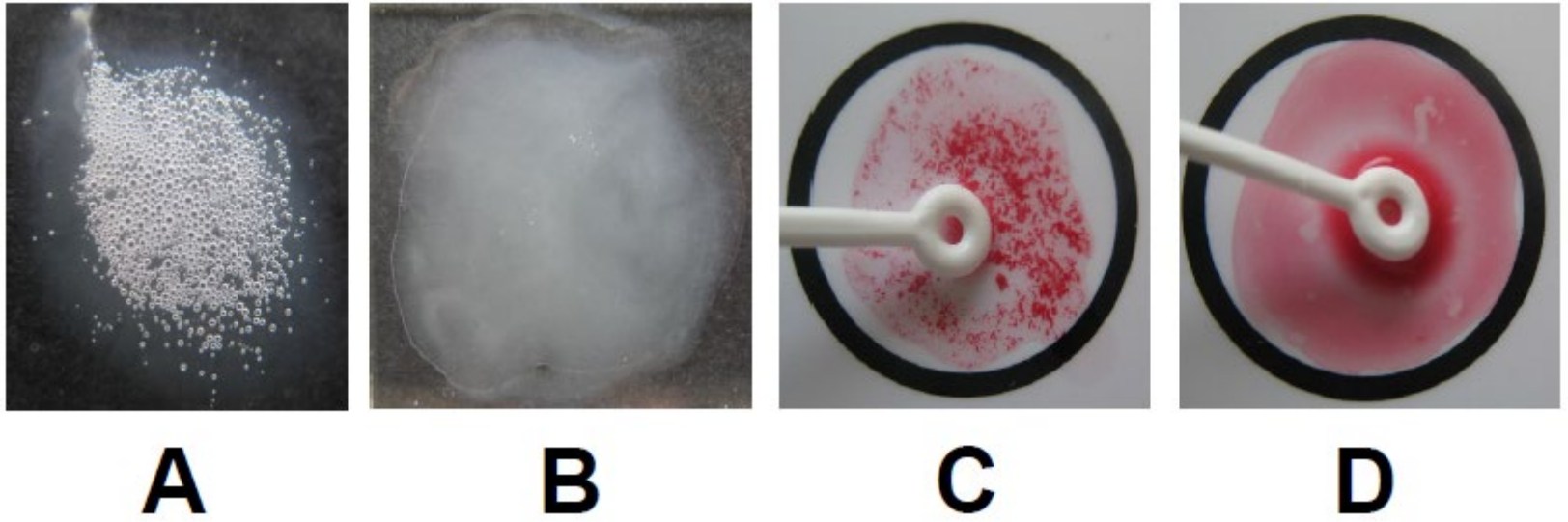

Figure 3. Staphylococci are catalase positive species releasing O_2 from hydrogen peroxide (A) and hence differentiated from hemolytic streptococci which are catalase negative (B). *S. aureus* as coaglulase positive species clotting fibringen to fibrin (C) comparing with cogulase negative staphylococci which do not (D).

d) Biochemical identification: To identify an isolate on species level multiple metabolic enzymes should be tested by the key dichotomous method or by numerical identification (see chapter – Identification).

e) Genotypical identification: Amplification of a specific DNA fragment (in bacteria usually
specific for 16S rRNA or a selected house-keeping gene) and/or their sequencing (see
chapter – Identification).

f) Susceptibility testing : Qualitative (disk diffusion method), quantitative methods or their
combination (E test) are used to test the susceptibility to various antibiotics (see chapter
5 – Antibiotic susceptibility). More than two thirds of staphylococcal strains are resistant
to penicilin G because of plasmid encoded β-lactamases that hydrolyse the