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# External ocular bacterial infections among Sudanese children at Khartoum State, Sudan

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Ocular infections are widespread and they exert heavy burden on eye health. Virtually, any eye component can be infected by a diversity of bacteria. The present study was performed to determine the prevalence of external ocular bacterial infections and to find out antibiotic susceptibility pattern of bacterial isolates at eye care hospitals in Khartoum, Sudan. Two hundred and four corneal scrape and drained pus materials were received from infected eyes with clinical diagnoses of bacterial conjunctivitis, keratoconjunctivitis, keratitis, blepharo-conjunctivitis, blepharitis, dacryo-cystitis and eye abscess. Culture, microscopy with Gram's stain of both samples, bacterial colonies and biochemical tests were carried out. Antibiotic susceptibility analysis using Kirby–Bauer disc diffusion test and standard table of antibiotic susceptibility was performed. Out of 204 samples processed, 130 (63.7%) yielded bacterial growth. The most prevalent bacterial eye infection was conjunctivitis (59.2%). Of all the isolates, 75 (57.7%) were Gram's positive and 55 (42.3%) were Gram's negative. Coagulase positive *Staphylococcus aureus* were the most prevalent, 39 (30%) followed *by Streptococcus pneumonia* 31 (23.8%), *Haemophilus influenzae* 22 (16.9%), *Pseudomonas aeruginosa* 13 (10%) and *Neisseria gonorrheae* 10 (7.7%). Gram positive bacteria were highly sensitive to vancomycin (95%), followed by chloramphenicol and ciprofloxacin (91%) and ceftriaxone (84%), while the majority were resistant to penicillin (72%). Gram-negative organisms were highly susceptible to amikacin (92.7%) followed by ceftriaxone (87.3%) and ciprofloxacin (78.2%). Major resistance was towards cotrimoxazole (82%) and ampicillin (73%).

**Key words:** External ocular bacterial infections, bacterial isolate, antibiotic susceptibility, normal flora, pathogenic bacteria.

## INTRODUCTION

Eye is protected by epithelia and mucous membranes which both serve as mechanical, chemical and biological barriers against pathogens (Bolaños-Jiménez et al., 2015). Tearing is an innate immunity mechanism that

flushes foreign particles from the ocular surface and act as a transport vehicle for the transfer of antimicrobial proteins and immunoglobulins (Akpek and Gottsch, 2003).

Like other mucosal surfaces, eyes are covered with protective resident microbial flora (Linden et al., 2008). Normal microbial flora of eye secretes antibacterial substances and competes with pathogenic bacteria for site and nutrients (Venkataraman et al., 2015).

Micro-organisms such as viruses, bacteria, unicellular parasites and fungi as well as multicellular parasites are capable of attacking both the surface and the interior of the eye giving rise to ocular diseases. This is the outcome of the interplay between invading organism's strong virulence factors and the host's depressed resistance. Poor personal hygiene, unfortunate living conditions, low socio-economic class and decreased immune status can lead to depressed host resistance (Tesfaye et al., 2013). Bacteria are the most frequent causative agents of ocular infections that might possibly culminate in loss of vision and this justifies the need for prompt treatment of serious bacterial eye infections that threatens the eye (Ubani, 2009).

Ocular infections include conjunctivitis and keratitis. These infections can damage structures of the eyes if left untreated, leading to considerable disabilities including blindness (Ubani, 2009). Other eye infections encompass dacryocystitis, dacryoadenitis, cellulitis and eye abscess (Brissette et al., 2011). Bacterial blepharitis represents another important ophthalmic infection (Bertino, 2009).

The most common worldwide mild eye infections detected in primary care clinic is conjunctivitis (Hovding, 2008). Bacterial conjunctivitis, or red eye, involves inflammation of the conjunctival mucosa. According to the American Academy of Ophthalmology Cornea and External Disease, this condition is more common in young children and the elderly than in other age groups (American Academy of Ophthalmology Cornea, 2011). The most common aetiological pathogens in bacterial conjunctivitis are *Staphylococcus aureus*, *Streptococcus pneumonia*, *Haemophilus influenzae*, *Staphylococcus epidermidis*, *Enterococcus* spp., *Moraxella* spp., *Streptococci viridans* group, *Escherichia coli*, *Serratia marcescens*, *Pseudomonas aeruginosa* and *Proteus mirabilis* (Bartlett and Jaanus, 2008; Cavuoto et al., 2008). Staphylococcal infections predominate in adults while *S. pneumoniae* and *H. influenzae* are more prevalent in children (Cavuoto et al., 2008).

Bacterial keratitis is another entity of ocular infections that might follow corneal epithelial barrier disruption due to injury or trauma with subsequent ulceration and infiltration of inflammatory cells (Kaliamurthy et al., 2013). The usual organisms responsible for such infections include Gram-positive bacteria such as *S. aureus, S. epidermidis* and several *Streptococcus* and *Bacillus* spp. as well as Gram-negative bacteria like *P. aeruginosa, Moraxella* spp*.* and *Haemophilus* spp*.* Corneal scarring or perforations are possible devastating outcomes, the avoidance of which necessitates immediate diagnosis and treatment (Rahimi et al., 2015).

Bacterial blepharitis is an infection of the eyelid margin with subsequent engorgement, congestion and eyelashes crusting (Rahimi et al., 2015). Bacterial blepharitis is mostly caused by *S. aureus* and coagulase negative staphylococci (CoNS) (Musa et al., 2014).

Dacryocystitis is painful inflammation of the lacrimal sac. Obstruction of the nasolacrimal duct, whether congenital or acquired is a known predisposing factor (Rahimi et al., 2015). The most common isolates in dacryocystitis are P*. aeruginosa, S. aureus, Enterobacter aerogenes, Citrobacter, S. pneumoniae, E. coli* and *Enterococcus* spp. (Briscoe et al., 2005; Kubal and Garibaldi, 2008).

Dacryoadenitis is a related condition in which there is inflammation and infection of the lacrimal gland. It can be caused by a variety of bacterial agents including *S. aureus, Neisseria gonorrheae* and streptococci. Clinically, it causes pain, redness, swelling, tearing and discharge over the lacrimal gland (the lateral one-third of the upper eyelid) (Brissette et al., 2011).

Cellulitis is bacterial infection of the periocular tissue. The condition can be serious to the extent of causing vision loss (Stratton et al., 2015). It can be classified as preseptal cellulitis, orbital cellulitis, subperiosteal abscess, intraorbital abscess and cavernous sinus thrombosis related cellulitis (Gonzalez and Durairaj, 2010). Preseptal cellulitis (PC) is defined as an inflammation of the eyelid and surrounding skin with eyelid abscess being a possible outcome (Akçay et al., 2014). The most frequent pathogen implicated in the etiology of this group of ocular infections is *H. influenza* (Stratton et al., 2015). Currently, *S. aureus* and *Streptococcus* species cause the majority of culture positive cases of preseptal cellulitis (Gonzalez and Durairaj, 2010). This is particularly noticeable when there are co-existing local wounds (Stratton et al., 2015).

Regardless of the predisposing factor beyond eye lid abscess, local skin flora such as *S. aureus* is the classical causative agents (Rutar et al., 2005).

Specific antibacterial agents are the corner stone in the management of bacterial ocular infections. Defining the specific antibacterial drug requires isolation and identification of bacterial pathogens along with antibiotics susceptibility analysis (Sharma, 2011). The empirical choice of an effective treatment is becoming more difficult as ocular pathogens are increasingly becoming resistant to commonly used antibiotics (Khosravi et al., 2007). Bacterial resistance is influenced by pathogens characters and antibiotic-prescribing practices including the widespread use of systemic antibiotics together with the applied health care guidelines (Bertino, 2009).

The present study aimed at determining bacterial isolates of external eye infections among Sudanese children patients at Khartoum state in addition to studying

the distribution of the common bacterial isolates in the specific clinical entities of bacterial conjunctivitis, kerato-conjunctivitis, keratitis, blepharo-conjunctivitis, blepharitis, dacryo-cystitis and eye abscess. It also worked towards finding out the distribution of these bacterial isolates among age groups and gender as well as assessing the *in vitro* susceptibility of these ocular bacterial isolates to the commonly used antibiotics in Sudan.

## MATERIALS AND METHODS

### Study design

This is a cross-sectional study that included patients with clinically diagnosed bacterial conjunctivitis, keratoconjunctivitis, keratitis, blepharo-conjunctivitis, blepharitis, dacryo-cystitis and eye abscess. All patients were diagnosed by a number of ophthalmologists using standard protocols.

### Ethical consideration

The study was approved by the National Ethical Committee, Ministry of Health Sudan. Permissions were taken from all hospitals administrations which were involved in this study. Written consents were obtained from every participant when applicable, or their caretakers before the enrollment in the study.

### Study samples

Patients who had eye infection with occurrence of mucus and pus with the clinical diagnoses of bacterial conjunctivitis, keratoconjunctivitis, keratitis, blepharo-conjunctivitis, blepharitis, dacryo- cystitis and eye abscess were included in this study. The patients were of different ages, from 1 day to 15 years old. A total of 204 samples were collected from patients attending the Ophthalmology Teaching Hospital and Noor Al-Oyoon Hospital. Patients or alternatively their caretakers were signed informed consents. Purulent material from the surface of lower conjunctival sac and inner canthus of eye were aseptically collected by sterile saline pre-moistened swabs. In abscesses cases, abscesses were incised and the drained pus was obtained. This was done before the instillation of antimicrobial or steroidal eye-drops for treatment. Sample collection was done by ophthalmologists taking care of the participants. The samples were transferred to laboratory immediately in cold box for bacteriological examination.

### Culture and identification

For each patient, a portion of the corneal scrape and the drained pus materias obtained were used for direct microscopy (Gram-stained smear) while the remaining material was inoculated directly onto the following media: blood agar, chocolate blood agar and MacConkey agar that support the growth of bacteria. Plates were incubated at temperature of 37°C. Aerobic atmospheric condition was maintained for the blood agar and the MacConkey agar while 10% carbon dioxide ($CO_2$) atmosphere was provided for the chocolate agar. All plates were initially examined for growth after 24 h and culture with no growth were re-incubated for further 48 h.

The bacteria isolated were identified by standard bacteriological test methods. Pure isolates of bacterial pathogens were preliminary characterized by colonial morphology and Gram-stain. Other biochemical procedures were used for full identification of Gram-positive and negative bacteria which included motility, indole, urease, oxidase, catalase and lactose fermentation tests. The pattern of utilization of X and V factors (Oxoid, Hampshire, UK) was employed for *Haemophilus* spp. characterization. Catalase and coagulase tests as well as haemolysis pattern on blood agar were used for identification of Gram-positive bacteria. Optochin sensitivity test was performed to identify *S. pneumoniae* and tributryin strips (Sigma Aldrich- Germany) were used for identification of *Moraxella catarrhalis*.

### Antimicrobial susceptibility testing

Isolates that were identified were tested for their susceptibility to a range of antibiotics using Kirby–Bauer disc diffusion test according to the clinical and laboratory standards institute (CLSI) guidelines. Antimicrobial susceptibility testing was performed for bacterial isolates by using the following antibiotics supplied by Oxoid Ltd.: amikacin (30 μg), chloramphenicol (30 μg), ciprofloxacin (5 μg), gentamicin (10 μg), co-trimoxazole (25 μg), ceftriaxone (30 μg) and amoxicillin (10 μg). Mueller-Hinton agars (oxoide) were used for the antibiotic sensitivity screen for non fastidious bacteria and 5% defibrinated blood was added along with Muller–Hinton agar for fastidious bacteria. Antibiotic discs added to Muller–Hinton plates were incubated at their respective optimal temperature and then the zones of inhibition diameters were measured. The results were interpreted according to the Clinical Laboratory Standards Institute (CLSI) guidelines as sensitive, intermediate and resistant (CLSI, 2014).

### Statistical analysis

Statistical analysis was performed using SPSS version 16 software. The associations of sociodemographic and clinical data to isolated pathogens were carried out by using the Pearson Chi-square test. P-value ≤ 0.05 was considered as statistically significant.

## RESULTS

A total of 204 children with external bacterial eye infection were studied. Of all, 130 (63.7%) were males and 74 (36.3%) were females. Age ranges from 1 day to 15 years old with the mean age of the study subjects being 3.3 years (Table 1). The predominant age group was 0-3 years. Bacterial isolation in both sexes (P-value = 0.28) and various age groups (P-value = 0.58) did not show statistical significance. Out of 204 cultured eye

**Table 1.** Frequency of isolated bacteria in relation to gender and the various age groups.

| Age (years) | Number | Gender | | Percentage (%) |
| --- | --- | --- | --- | --- |
| | | Male | Female | |
| 0-3 | 63 | 37 | 26 | 54 |
| 4-7 | 19 | 6 | 13 | 11 |
| 8-11 | 26 | 16 | 10 | 12 |
| 12-15 | 22 | 12 | 10 | 23 |
| Total | 130 | 71 | 59 | 100 |

**Table 2.** Distribution of bacterial pathogens among clinical features of external ocular infection.

| Bacterial isolates | Type of ocular infection | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | Conjunctivitis n=77 | Kerato-conjunctivitis n=4 | Keratitis n=27 | Blepharo-conjunctivitis n=4 | Abscesses n=4 | Blepharitis n=10 | Dacryo-cystitis n=4 | |
| *S. aureus* | 24 | 0 | | 2 | 4 | 6 | 3 | 39(30% |
| *S. pneumonia* | 9 | 0 | 17 | 0 | 0 | 4 | 1 | 31 (23%) |
| CoNS | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 5 (4%) |
| *N. gonorrhoeae* | 6 | 4 | | 0 | 0 | 0 | 0 | 10(7.7%) |
| *P. aeruginosa* | 9 | 0 | 4 | 0 | 0 | 0 | 0 | 11(8.3%) |
| *Klebsiella* | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 4 (3.1%) |
| *E. coli* | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 (1.5%) |
| *M.catarrhalis* | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 4 (3.1%) |
| *H. influenzae* | 20 | 0 | 2 | 0 | 0 | 0 | 0 | 22(17%) |
| Total | 77 (59.2%) | 4(3.1%) | 27 (20.7%) | 4 (3.1%) | 4 (3.1%) | 10 (7.7%) | 4 (3.1%) | 130(100%) |

discharges, 130 (63.7%) bacterial isolates were identified.

Based on the clinical categorization, the predominant ocular bacterial infections were conjunctivitis (59.2%) followed by keratitis (20.7%), blepharitis (7.7%), keratoconjunctivitis (3.1%), dacryocystitis (3.1%), eye abscess (3.1%) and blepharoconjunctivitis (3.1%) (Table 2).

The orderly proportions of bacteria isolated regardless of their Gram staining were coagulase positive *S. aureus* 30.0% (39 of 130) followed by *S. pneumonia* 23.8% (31 of 130), *H. influenzae* 16.9% (22 of 130), *P. aeruginosa* 10% (13 of 130), *N. gonorrhoeae* 7.7% (10 of 130), CoNS (coagulase-negative *staphylococci*) 3.9% ( 5 of 130), *Klebsiella* 3.1% (4 of 130), *M. catarrhalis* 3.1% (4 of 130) and last of all *E. coli* 1.5% (2 of 130) (Table 3).

According to the categorization into Gram positive and negative, 57.7% of the bacterial isolates were Gram-positive (75 of 130) whereas, Gram negative bacteria comprised 42.3% of all

isolates (55 of 130) (Table 2). Of the 75 isolated Gram-positive bacteria, the orderly proportions of the isolates were as follows: coagulase positive *S. aureus* 52.0% (39 of 75), *S. pneumonia* 41.3% (31 of 75) and CoNS 6.7% (5 of 75) (Table 2). Of the 55 isolated Gram-negative bacteria, the orderly proportions of the isolates were: *H. influenza* 40.0% (22 of 55), *P. aeruginosa* 23.6% (13 of 55) *N. gonorrhoeae* 18.2 % (10 of 55), *Klebsiella* 7.3% (4 of 55)*, M.catarrhalis* 7.3% (4 of 55) and last of all *E. coli* 3.6% (2 of 55) (Table 2). The fractions of isolates from the different clinical entities studied were as follows: Conjunctivitis: *S. aureus* (31.1%), *H. influenza* (26%), *P. aeruginosa* (11.7%), *S.pneumoniae* (11.7%), *N. gonorrhoeae* (7.8%), CoNS (3.9%), *M. catarrhalis* (2.6%), *Klebsiella* spp. (2.6%) and *E. coli* (2.6%) (Table 2).

Kerato-conjunctivitis cases were totally caused by *N. gonorrhoeae (*100%) (Table 2). Keratitis cases were caused by *S. pneumonia* (63%), *P. aeruginosa,* (14.8%)*,* CoNS (7.4%), *Klebsiella* spp. (7.4%) and *H. influenza* (7.4%) (Table 2).

Blepharo-conjunctivitis cases were caused by S. *aureus* (50%) and *M. catarrhalis (*50%). Abscesses cases were totally caused by S. *aureus* (100%) (Table 2). Blepharitis cases were caused by S. *aureus* (60%) and *S. pneumonia (*40%) (Table 2). Dacryo-cystitis cases were caused by S*. aureus* (75%) and *S. pneumonia* (25%) (Table 2). Based on antibiotic susceptibility patterns, collectively, the Gram-positive cocci (*S. aureus,* CoNS and S*. pneumonia)* were highly sensitive to vancomycin (71 of 75; 95%), chloramphenicol and ciprofloxacin (68 of 75; 91%) for each followed by ceftriaxone (63 of 75; 84%). The majority of Gram-positives showed resistance against penicillin (54 of 75; 72%) as shown in Table 3. Individual antibiotic susceptibility patterns of Gram positive bacteria were as follows:

S. *aureus* showed high susceptibility to vancomycin (35 of 39; 90%), ciprofloxacin (33 of 39; 85%), chloramphenicol (32 of 39; 82%), amikacin (30 of 39; 77%), cotrimoxazole (30 of 39; 77%), gentamicin (29 of 39; 74%) and

**Table 3.** Antimicrobial susceptibility patterns of isolated bacteria.

| Bacteria | No of isolates | s/r | P | AMP | TE | E | C | CN | CIP | CRO | AK | COT | VA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *S. areus* | 39 | S | 0 ( 0) | 14 (36) | 11 (28) | 28 (72) | 32(82) | 29 (74) | 33(85) | 29(74) | 30(77) | 30(77) | 35(90) |
| | | R | 39 (100) | 25 (64) | 28 (72) | 11( 28) | 7 (18) | 10 (26) | 6 (15) | 10(26) | 9(23) | 9(23) | 4(10) |
| CoNS | 5 | S | 1 (20) | 1(20) | 2 (40) | 4 (20) | 5 (100) | 1 (20) | 5(100) | 4(80) | 3 (60) | 2(40) | 5(100) |
| | | R | 4 (80) | 4 (80) | 3 (60) | 1(80) | 0 | 4(80) | 0 | 1(20) | 2(40) | 3(60) | 0 |
| *S. pneumoniae* | 31 | S | 20 (64.5) | 13(42) | 15 (48) | 26(84) | 31(100) | 22 (71) | 30(97) | 30(97) | 22(71) | 25(81) | 31(100) |
| | | R | 11(35.5) | 18(58) | 16(52) | 5(16) | 0 | 9(29) | 1(3) | 1(3) | 9(29) | 14(19) | 0 |
| *H. influenzae* | 22 | S | NT | 11(50) | 18(82) | 18(82) | 19(86) | 22(100) | 20(91) | 21(95) | 18(81) | 3(18) | NT |
| | | R | | 11(50) | 4(18) | 4 (18) | 3(14) | 0 | 2(9) | 1 (5) | 4(19) | 19(86) | |
| *N. gonorrheae* | 10 | S | 7 (70) | 4(40) | 8(80) | 9(90) | 9(90) | 0 | 10(100) | 10(100) | 10 (100) | 2 (20) | NT |
| | | R | 3 (30) | 7(60) | 2(20) | 1(10) | 1(10) | 10(100) | 0 | 0 | 0 | 8(80) | |
| *P. aeruginosa* | 13 | S | - | 0 | 2 (15) | NT | 1(9) | 0 | 6(46) | 8(62) | 13(100) | 1(8) | NT |
| | | R | - | 13(100) | 11(85) | NT | 12(91) | 13(100) | 7(54) | 5(38) | 0 | 12(92) | |
| *Klebsiella* spp. | 4 | S | - | 1(25) | 0 | - | 1(25) | 2(50) | 2(50) | 3(75) | 4(100) | 1(25) | NT |
| | | R | - | 3(75) | 4(100) | - | 3(75) | 2(50) | 2(50) | 1(25) | 0 | 3(75) | |
| *M. catarrhalis* | 4 | S | 0 | 0 | 3(75) | NT | 4(100) | 4(100) | 4(100) | 4(100) | 4(100) | 1(25) | NT |
| | | R | 4 | 4 | 1(25) | NT | 0 | 0 | 0 | 0 | 0 | 3(75) | |
| *E.coli* | 2 | S | - | 0 | 1(50) | NT | 0 | 1(50) | 1(50) | 2(100) | 2(100) | | NT |
| | | R | - | 2(100) | 1(50) | NT | 2(100) | 1(50) | 1(50) | 0 | 0 | | |

CoNS=Coagulase negative staphylococcus, S=sensitive, R= resistance, P=penicillin AMP=Ampicillin, TE=tetracyclin, E=erythromycin, C= chloramphenicol, CN=gentamicin, CIP=ciprofloxacin, CRO=cefrtiaxone, AK= amikacin, COT=cotrimoxazole, VA= vancomycin.

erythromycin (28 of 39; 72%). On the other hand, they were totally resistant to pencillin (39 of 39; 100.0%) and resistant to lesser extents to tetracycline (28 of 39; 72%) and ampicillin (25 of 39; 64%) (Table 3). *S. pneumoniae* showed complete susceptibility to vancomycin and chloramphenicol (31 of 31; 100%) for each and lesser susceptibility to ceftriaxone and ciprofloxacin (30 of 31; 97%) for each, erythromycin (26 of 31; 84%) and cotrimoxazole (25 of 31; 81%.) conversely, more than half of *S. pneumoniae* showed resistance against ampicillin (18 of 31; 58%) and tetracycline (16 of 31; 52%)

(Table 3). CoNS were totally susceptible to vancomycin, ciprofloxacin and chloramphenicol (5 of 5; 100%) for each. The majority of bacteria isolates were resistant to penicillin, ampicillin and gentamicin (4 of 5; 80%) for each (Table 3). For Gram-negative organisms (*H. influenzae, P. aeruginosa, N. gonorrhoeae, Klebsiella, M. catarrhalis* and *E. coli*) as a group, the highest susceptibility was to amikacin (92.7%; 51 of 55), followed by ceftriaxone (87.3%; 48 of 55) and ciprofloxacin (78.2%; 43 of 55). Major resistance was to cotrimoxazole (45 of 55; 82%) and ampicillin (40 of 55; 73%) (Table 3). Individual

antibiotic susceptibility pattern of Gram negative bacteria were as follows: *H. influenzae* were found to be sensitive to gentamicin (22 of 22; 100%) followed by cefrtiaxone (21 of 22; 95%), ciprofloxacin (20 of 22; 91%), chloramphenicol (19 of 22; 86%) and amikacin (18 of 22;81%), whereas the highest resistance was to cotrimoxazole (19 of 22; 86%) (Table 3).

*P. aeruginosa* showed complete sensitivity to amikacin (13 of 13; 100.0%) and less sensitivity to cefrtiaxone (8 of13; 62.0%). However, they displayed complete resistance towards gentamicin and ampicillin (13 of 13; 100.0%) for each and

high resistance to cotrimexazole and chloramphenicol (12 of 13; 92.0%) for each followed by tetracycline (11 of 13; 85.0%). *N. gonorrhoeae* were fully susceptible to amikacin, ceftriaxone, ciprofloxacin and gentamicin (10 of 10; 100%) for each. Conversely, they showed extreme resistance to gentamicin (10 of 10; 100%) followed by cotrimoxazole (8 of 10; 80%) and ampicillin (7 of 10; 60%) (Table 3). *Klebsiella* species showed full susceptibility to amikacin (4 of 4; 100%), total resistance to tetracycline (4 of 4; 100%) and high resistance to ampicillin, cotrimoxazole and chloramphenicol (3 of 4; 75%) for each.

*M. catarrhalis* were fully susceptible to amikacin, ceftriaxone, ciprofloxacin, chloramphenicol and gentamicin (4 of 4; 100%) for each and fully resistant to penicillin and ampicillin (4 of 4; 100%) for each.

*E. coli* were completely susceptible to amikacin and ceftriaxone (2 of 2; 100%). 50% strains of *E. coli* species were sensitive to ciprofloxacin, gentamicin and tetracycline, whereas the isolates showed full resistance to both ampicillin and chloramphenicol (2 of 2; 100%).

## DISCUSSION

The eye and its associated structures are uniquely predisposed to infections by various organisms, mainly, bacteria, viruses and fungi and rarely parasites. The results of the current study are showing significant similarities as compared to other analogous ones, nevertheless when it comes to certain particular aspects, striking differences has been noted between the present findings and their equivalent ones in other surveys.

In this study, the overall prevalence of bacterial eye infections was 63.7% where as 36.3% of clinical samples did not show bacterial growth. Similar studies conducted in Ethiopia concluded that the prevalence was 54.2, 60.8, 59.4 and 60.8% (Anagaw et al., 2011; Muluye et al., 2014; Assefa et al., 2015; Shiferaw et al., 2015). Parallel works in India concluded the prevalence was 58.8 and 61% (Bharathi et al., 2010; Ramesh et al., 2010). The cause of absence of bacterial growth in clinically diagnosed cases might be bacterial causes not identified by the conventional laboratory parameters or non-bacterial causes like viruses and fungi or non infective causes like eye allergies.

Almost half of the bacterial isolates (48.5%) were from patients in the age group of less than three years of life. Susceptibility to infection is increased in babies due to low immunity at such ages (Niewiesk, 2014). In addition to this, the air facilitates the transfer of bacteria to hospital delivery rooms especially when opening the doors and windows (Al-Oqaili., 2004).

Gram positive bacteria were the dominant isolate (57.7%) in the current study. This is supported by other studies conducted in Ethiopia and Nigeria (Bharathi et al., 2010; Shiferaw et al., 2015). Among the Gram positive bacteria, *S. aureus* was the most common pathogen with an overall prevalence of 30% equivalent to 52% of Gram positive bacteria. Previous reports showed that *S. aureus* was the most predominant isolated pathogen from ocular infections (Chaudhry et al., 2005a; Ubani, 2009; Bharathi et al., 2010; Ramesh et al., 2010; Anagaw et al., 2011; Tesfaye et al., 2013; Musa et al., 2014). These findings reflect the known high virulence of these bacteria. Other studies showed that that CoNS was the most frequent bacteria involved in eye infections (Anagaw et al., 2011; Muluye et al., 2014; Assefa et al., 2015). This may be due variations in climatic, geographical and ethnic parameters.

Gram negative bacteria were less dominant (43.3%) with *H. influenza* heading the list with an overall prevalence of 17% of all isolates equivalent to 40% of Gram negative isolates. On the other hand, *M. catarrhalis* had a lesser frequency (3.1%) of all isolates. This finding is in agreement with a previous study (Tesfaye et al., 2013). However, in other works, the major isolate was *M. catarrhalis* (Bharathi et al., 2010), *E. coli* (Assefa et al., 2015), *Proteus* species (Musa et al., 2014) and *P. aeruginosa* (Tesfaye et al., 2013).

This study showed limited isolates of enteric bacteria (5%) which is comparable to the finding of another study (Tesfaye et al., 2013) and contrary to those of other ones (Esenwah, 2005; Anagaw et al., 2011). This can be ascribed to factors related to the communities studied and their surrounding conditions plus biological disparities of the isolates. The study showed that the most common bacterial ocular infections is conjunctivitis (59.2%), the second most frequent one is keratitis (20.7%) followed by blepharitis (7.7%) whereas keratoconjunctivitis, dacryocystitis, blepharoconjunctivitis and eye abscesses had the same frequency (3.1%).

In the present work, many bacteria were isolated from patients with conjunctivitis. These are in the order: *S. aureus* (31.1%), *H. influenza,* (26%), *P. aeruginosa* (11.7%), *S. pneumoniae* (11.7%), *N. gonorrhoeae* (7.8%), CoNS (3.9%), *M. catarrhalis* (2.6%), *Klebsiella* spp. (2.6%) and *E. coli* (2.6%). Comparable studies reported *S. aureus* as the predominant bacteria in conjunctivitis (Bharathi et al., 2010; Ramesh et al., 2010).

*S. pneumoniae* was found to be the main isolate in cases of microbial keratitis (63%) followed by *P. aeruginosa,* (14.8%)*,* CoNS (7.4%), *Klebsiella* spp*.* (7.4%) and *H. influenzae* (7.4%). This finding is in agreement with those of similar studies conducted in Ethiopia and India (Alemayehu, 2004; Bharathi et al., 2010). One study in India reported *P. aeruginosa* and *S. pneumoniae* as the predominant isolates of microbial keratitis with equal frequency (Geethakumari et al., 2011). In contrast, other studies reported P. *aeruginosa* as the major isolate (Bharathi et al., 2010; Tesfaye et al., 2013). Another study concluded that *S. aureus* are the most common bacterial pathogens isolated in keratitis (Kaliamurthy et al., 2013). This may be due to inter-

population variations and environmental dissimilarities in different countries (Janumala et al., 2012). The most common infection of lacrimal apparatus is dacryocystitis (Ramesh et al., 2010).

Obstruction of the nasolacrimal duct provides a good environment for bacterial proliferation leading to secondary bacterial infection (Ramesh et al., 2010). In this study, the prevalence of *S. aureus* was the highest among dacrocystitis isolates followed by *S. pneumoniae*. This is consistent with the findings of other surveys (Chaudhry et al., 2005b; Assefa et al., 2015) and is discordant with other works which reported *S. pneumoniae* as the most prevalent isolate (Ramesh et al., 2010; Kebede et al., 2010).

In this study, *S. aureus* was the sole isolated bacteria in all cases of orbital cellulitis with eyelid abscess. This finding is compatible with previous studies that reported *S. aureus* as the predominant pathogen involved in this type of ocular infections (Blomquist, 2006; Akçay et al., 2014). From the abovementioned findings and comparative analysis, different organisms are implicated in the etiology of infections targeting this disease-prone organ in the population under study. Some of these organisms are part of normal flora and some are not.

Despite the fact that *Staphylococci* and *Streptococci* along with other bacteria like *Haemophilus*, *Moraxella* and some *Neisseria* spp. are part of the normal flora of the conjunctiva; under certain circumstances they become involved in ophthalmic infections (Bharathi et al., 2010). Non-pathogenic *Neisseria* spp. that are normal commensals of mucosal surfaces include *N. lactamica*, *N. sicca* and others (Liu et al., 2015).

The principle routes of acquisition of the pathogens are airborne droplets, eye contact with contaminated hands and spread from nearby body sites (Ramesh et al., 2010). A variety of virulence and predisposing factors are involved in these infections.

*S. aureus* which heads the lists of pathogenic bacteria in the current study possess cell surface factors like antiphagocytic capsule and secreted virulence factors like hemolysins and leukocidin (Costa et al., 2013). *S. pneumoniae* which comes in the second place is frequently found in the lacrimal apparatus and conjunctiva as normal flora. Minor corneal epithelial disruption predisposes to its invasion and consequently corneal infection (Bharathi et al., 2010). High virulence of *H. infleuenzae* which occupies the third position can be explained by features like capsule, adhesions molecules and pilli (Kostyanev and Sechanova, 2012). Concerning the less prevalent organisms in the current work, *Pseudomonas* possess factors like glycocalyx and pili for adherence while the biofilms which coat them facilitate their attachment to their targets (Al-Mujaini et al., 2009). They also cause corneal stroma melting due to enzymatic effects (Marquart et al., 2013). *N. gonorrhoeae* virulence factors include pili, porin and Opa proteins (van Vliet et al., 2009). Low immunity and medical devices use

predispose to CoNS infections (Becker et al., 2014). *Moraxella* spp. use adhesions and can evade complement system (Perez Vidakovics and Riesbeck, 2009). *Klebsiella* have prominent antiphagocytic capsule and *magA* (Hunt et al., 2011). Vulnerability to *E. coli* induced conjunctivitis is related to young ages (Wiwanitkit, 2011) especially neonates in healthcare institutes (Goel et al., 2016).

Gram-positive cocci were highly susceptible to vancomycin (95%), chloramphenicol and ciprofloxacin (91%) and ceftriaxone (84%). A similar study conducted in India revealed that vancomycin and chloramphenicol had the highest efficacy against Gram positive isolates (Ramesh et al., 2010; Bharathi et al., 2010). These findings contrast with those obtained from studies carried out in India and Ethiopia which reported higher susceptibility to ciprofloxacin as compared to vancomycin (Bharathi et al., 2010; Tesfaye et al., 2013). However, one study conducted in Iran reported low coverage of vancomycin against *S. aureus* (Khosravi et al., 2007). The persistent conclusion of vancomycin as an antibiotic with high effectiveness against ocular Gram-positive isolates might be attributed to the fact that vancomycin inhibits early stages in cell wall mucopeptide synthesis.

In this study, all *S. aureus* strains were resistant to penicillin. This is very similar to previous reports from the studies performed among Ethiopian ocular infections (Bharathi et al., 2010; Anagaw et al., 2011). This can be explained by the well-known fact that most of *S. aureus* strains produce penicillinase and alternative penicillin binding protein (PBP-2A) rendering them resistant to most beta lactam antibiotics.

Gram negative bacteria were highly susceptible to amikacin (92.7%) followed by ceftriaxone (87.3%) and lastly ciprofloxacin (78.2%). This observation is consistent with those obtained from studies conducted in India, Ethiopia and Libya (Bharathi et al., 2010; Tesfaye et al., 2013; Musa et al., 2014). Yet, it is contradictive to the findings obtained from a recent study in Ethiopia which reported high susceptibility of Gram negative isolates to gentamicin along with resistance to ceftriaxone and ciprofloxacin (Anagaw et al., 2011).

## Conclusion and recommendations

Bacterial external ocular infections are of considerable prevalence among Sudanese pediatrics population. They are the cause of no less than two thirds of all cases. Gram positive bacteria constitute more than half of the isolates with *Staphylococcus* species being the most predominant ones. However, Gram negative bacteria have comparatively significant contribution to this category of diseases. Different antimicrobial susceptibility patterns were identified. Consequently, identification of potential pathogenic bacteria implicated in these infections through culture and biochemical tests

techniques as well as recognition of drug susceptibility pattern must be carried out as routine diagnostic laboratory tests for proper management. The etiological agents responsible for a considerable fraction of clinically diagnosed cases were not identified by conventional methods. Accordingly, workup of other causes like bacteria not recognized by traditional methods is required including sophisticated techniques such as molecular modalities. Non-bacterial infective organisms and non-infective agents should also be investigated.

## Conflicts of interest

The authors declare that there is no conflict of interest.

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