

Review Article

Nosocomial Infections and their Surveillance in Veterinary Hospitals

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Abstract | Nosocomial, or hospital-acquired, infections are well-thought-out to be the most common problem affecting hospitalized human patients as well as veterinary patients. These are of great consequence in veterinary medicine and can have considerable adverse effects on the individual patient as well as on the veterinary hospital as a whole. Different infectious agents like MRSA, *Cl. difficile*, MDR *E. coli*, *Salmonella* spp. and many more are of prodigious significance in causing NIs. A surveillance and control measure for these NIs in veterinary settings needs to be addressed in future. This review consolidates some Nosocomial infections and the strategy for its surveillance in veterinary practice.

Keywords | Nosocomial infections, Surveillance, Veterinary, Hospitals, MDR

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INTRODUCTION

Nosocomial infections are hospital acquired infections which may be localized or systemic form acquired by the patient who was admitted for reasons other than infection, because of the existence of an infectious agent or its toxin which was not present or incubating at the time of hospital admittance (Horan et al., 2008). Furthermore they are the high-flying reasons for the failure of advanced health treatment (Mielke, 2010). Generally Nosocomial infections are frequent impediment encountered by the hospitalized human beings, and nosocomial bloodstream infections are the eighth leading cause of death in the

United States (Burke, 2003). About 5–10% of patients acquire infections from human hospitals and approximately 90,000 deaths per year due to nosocomial infections (Burke, 2003). The risk factors in veterinary hospitals are comparable to those in human hospitals. Prevalence studies have shown that 4-9% patients endure from a nosocomial infection (Mielke, 2010). The occurrence of nosocomial infections in veterinary hospitals has not been well established and in nascent stage (Boerlin et al., 2001; Johnson, 2002; Morley, 2004; Smith, 2004; Traub-Dargatz et al., 2004; Morley and Weese, 2008), even though the nosocomial infections are of immense significance in the field of veterinary medicine since quite a lot of

nosocomial outbreaks of different etiologies in veterinary hospitals has been documented (Castor et al., 1989; Madewell et al., 1995; Hartmann et al., 1996; Konkle et al., 1997; Tillotson et al., 1997; Seguin et al., 1999; Schott et al., 2001; Weese and Armstrong, 2003; Cherry et al., 2004; Wright et al., 2005; Weese et al., 2006a; Dallap et al., 2010; Goehring et al., 2010; Steneroden et al., 2010). Six of those outbreaks had evidence of zoonotic infection (Konkle et al., 1997; Seguin et al., 1999; Schott et al., 2001; Cherry et al., 2004; Wright et al., 2005; Weese et al., 2006a).

HISTORY

In the middle ages, the hospitals were established to treat pitiable plague victims and to till date the hospitals and health care personnel are serving the society with great dedication and hospitals has become more obligatory in the healthy living of both human and animals. In 1869, Sir James Young Simpson did an initial signature in the field of hospital epidemiology by his study with more than 4000 amputees in Scotland and England where he found the mortality rate was higher in patients who remained in the hospital for post-operative care. He used the term “hospitalism” to express the risk linked to hospital care. After many years of dedicated works by people like Oliver Wendell Holmes, Ignaz Philipp Semmelweis, Louis Pasteur, Joseph Lister, and Robert Koch, to illuminate the risk factors connected with hospital-related infections (Semmelweis, 1848; Major, 1954; Eickhoff, 1981) and introduction of rectification guidelines like hand washing and sterilization of instruments used for surgery reduced the propagation of disease and death (Major, 1954). The “tide of complacency” in the history of control of nosocomial infection is after the discovery of antibiotics, since the understanding and research of nosocomial infections was not highly developed in the time of world wars (Eickhoff, 1981). In 19th century after the commencement of advanced research in medicine and surgery which revolutionised the healthcare facilities and interventions but also unearthed the unintended harm to patients i.e. Nosocomial infections through health care settings.

EPIDEMIOLOGY AND RISK FACTORS

Nowadays, some of the important factors which have been often associated with the nosocomial infections

in human health care centres like employing invasive devices (e.g., intravenous and urinary catheters), lengthened hospitalization of decisively ill patients, complex medical treatment and surgical procedures, and the extensive exploitation of antibiotics (Boerlin et al., 2001; Johnson, 2002) are increasing in veterinary hospitals. Intensive care Patients are at 5 to 10 times higher risk of developing a nosocomial infection than normal patients (Weber et al., 1999). The threat of developing infection for hospitalized patients are due to extrinsic risk factors, such as the use of invasive devices and intrinsic risk factors, like underlying ailment during hospitalization (National Nosocomial Infections Surveillance System, 1991; Emori and Gaynes, 1993). Nosocomial infections are either site specific (e.g., surgical site infection) or unit specific (e.g., intensive care unit). The possible source for nosocomial agents are the patient’s own flora, health personnel, instruments and equipment of hospital (Hardy et al., 2006; Marshal et al., 2009) (Figure 1). The amplifying risks which favours the transmission of antibiotic resistant pathogens and other nosocomial infections in veterinary hospitals are lack of hygiene, employing invasive devices, prolonged treatment, longer visits by health care worker and caseloads (D’Agata et al., 2012), delayed and breaks in treatment (D’Agata et al., 2008), lengthy hospital stay (D’Agata et al., 2007) and dependence on antimicrobials (Johnson, 2002; Morley et al., 2005), administration of antiulcer drugs (Ruple-Czerniak et al., 2013).

In one individual-based model study to scrutinize the effect of movement of dogs to various locations in a veterinary teaching hospitals, it was found out that nosocomial infection transmission is greater in diagnostic rooms, intensive care units and housing wards than operation theatre and lobby and it also revealed that transmission following the contact with health-care personnel was more common (Suthar et al., 2014). Veterinary hospitals are the major source and accountable for increasing prevalence of a MDR E. coli in horses (Ahmed et al., 2012). Veterinary personnel and veterinary hospital environments are allegedly most important key factors in risk of gaining antibiotic resistant pathogens by hospitalized dogs (Hamilton et al., 2013; Heller et al., 2010; KuKanich et al., 2012).

SPREAD OF NOSOCOMIAL INFECTIONS IN VETERINARY HOSPITALS

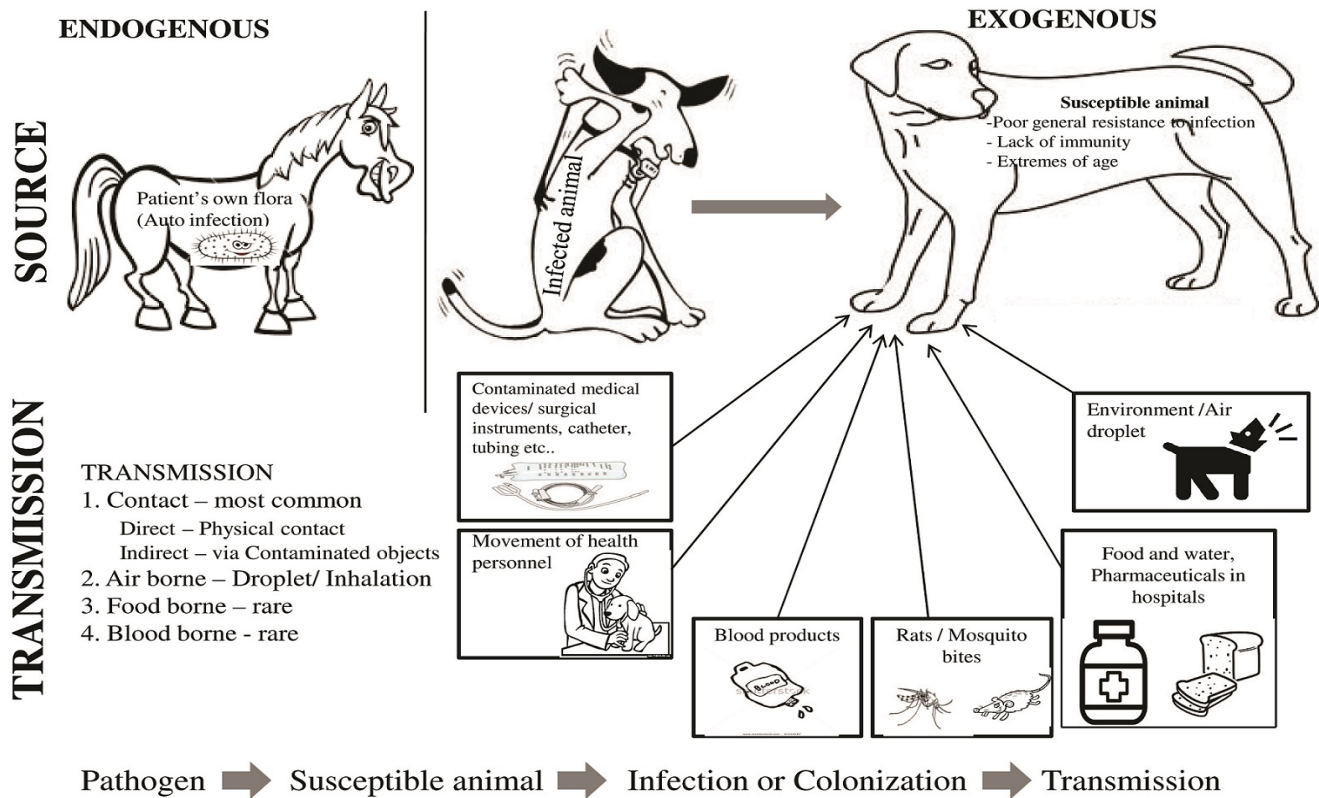


Figure 1: Spread of nosocomial infections in veterinary hospitals

IMPACTS OF VETERINARY HOSPITAL ASSOCIATED INFECTIONS

Nosocomial infections are the growing cause of morbidity and mortality in both human and veterinary medicine (Weese, 2008a; Weese, 2008b; Owens et al., 2008; Faires et al., 2010). Implication of multiple drug resistant bacterias in nosocomial infections are the main concern because of high morbidity, high cost and duration of treatment and more challenging to eliminate (Weese, 2008a; Owens et al., 2008; Faires et al., 2010) and there is potential zoonotic risk (Suthar et al., 2014). The food animals with resistant antimicrobial bacteria pose a serious public health risk (Howard et al., 2003), but the pet animals transmit the resistant bacteria directly to human population by acting as a reservoir (Guardabassi et al., 2004; Lloyd, 2007; Murphy et al., 2009; Song et al., 2013). MDR in companion animals encompass stern public health impacts (Abraham et al., 2014). Undue exploitation of antibiotics and horizontal gene transfer may lead to increased possession of antibiotic resistance, thereby escorting to longer period of antibiotic treatment and treatment failure (Levin et al., 2006; Bootsma

et al., 2012). The occupational risk to the veterinary health personnel and staff are other concern (Jordan et al., 2011). There will be huge economic loss due to this outbreaks and it may tarnish the reputation of the concerned veterinary hospital with reduced client confidence and increased panic.

MRSA

With all the evidence *Staphylococcus aureus* is an important pathogen of both human and animal causing meek skin infections to grave bacteraemia. Generally almost all *S. aureus* strains are resistant to beta-lactam antibiotics since it is producing pencillinases. Owing to this resistance, meticillin which is resistant to penicillinases were extensively used to treat *S. aureus* Infections. In late 1950s the meticillin use was initiated in human medicine to treat resistant *S. aureus* infections. Meticillin resistance was accounted in the early 1961 (Jevons, 1961) and the resistance development was demonstrated (Barber, 1961). In 1970s MRSA emerged as a staid public health issue in US hospitals (Panlilio et al., 1992). In 1990s MRSA expanded itself as a solemn nosocomial infection throughout the world (Ayliffe, 1997). Eventhough MRSA was first

emerged as a human pathogen, nowadays MRSA reports in animals are gradually increasing mainly in equine and companion animals. It is known that *S.aureus* is one of the chief cause for mastitis and the extensive use of intramammary antibiotics in cattle, so it is not unanticipated that, MRSA was isolated from milk of a mastitic animal, which is first among animals (Devriese et al., 1972). After this MRSA has been isolated from various species like dogs (Pak et al., 1999), cats (Scott et al., 1988), sheep (Goni et al., 2004), horses (Seguin et al., 1999), pigs (Voss et al., 2005) and chickens (Lee, 2003). Methicillin-resistant *Staphylococcus aureus* (MRSA) is an important concern nowadays in pet animals for being a significant cause in nosocomial infections (Weese, 2008b; Faires et al., 2010; Weese et al., 2010) and also a threat of zoonoses to veterinary health care personnel (Loeffler et al., 2010; Burstiner et al., 2010) and horses may act as a reservoir of MRSA and serve as a source of infection to humans (Weese et al., 2005a). Interestingly, various studies reported that MRSA isolated from companion animals like dogs and cats are found indistinguishable from MRSA isolated from human associated infections (Baptiste et al., 2005, Loeffler et al., 2005; O'Mahony et al., 2005; Middleton et al., 2005; Rich et al., 2005; Hanselman et al., 2006; Malik et al., 2006). The association was found out by various phenotypic typing and molecular typing methods like PFGE (O'Mahony et al., 2005), SCCmec, MLST (Enright et al., 2000), spa typing (Moodley et al., 2006). The data obtained through all these studies sturdily suggesting the bidirectional transmission of MRSA between companion animals and human (Leonard et al., 2006). Whereas with the assistance of epidemiological typing it is proved that strains of MRSA isolated from horses and equine associated personnel are different (Baptiste et al., 2005; O'Mahony et al., 2005; Weese et al., 2005a; Cuny et al., 2006). Outbreaks linking both horses and humans in veterinary hospitals were reported from the United States (Seguin et al., 1999), Canada (Weese et al., 2005a), Ireland (O'Mahony et al., 2005), Austria (Cuny et al., 2006, 2008), the Netherlands (van Duijkeren et al., 2010) Switzerland (Sieber et al., 2011) and Israel (Schwaber et al., 2013). The typing studies revealed that the MRSA isolated from pigs (Voss et al., 2005; Van Dijke et al., 2006) and cattle (Kwon et al., 2005) are distinct from MRSA of human lineage. Numerous studies have acknowledged the increasing MRSA infections in companion animals are coupled

with post-surgical infections and wounds (Rich et al., 2004; Leonard et al., 2006) and indwelling devices and suture materials (Leonard et al., 2006). Smith et al. (1989) accounted 38% isolation rate of bacteria in dogs from the orthopaedic implant fixation site soon after the removal following the union of the closed fracture (Smith et al., 1989). The primary route of MRSA infection transmission in veterinary hospitals is through hands of healthcare personnel (Leonard et al., 2006). As far as public health is concerned many years ago likelihood of companion animals to act as the source for the zoonotic infections of *Staphylococci* is suggested (Mann, 1959) and many reports have offered the suggestion that animals may act as reservoirs of MRSA infections to human. In one case a cat was involved as a MRSA source for nurses in geriatric care unit (Scott et al., 1988). In another case of two nurses, a dog was considered as a reservoir for the treatment failure for MRSA and reinfection (Cefai et al., 1994). Another interesting case of recurrent MRSA infection in a diabetic patient and his wife, the source was found out to be a dog after the sampling of dog's nares which is colonized with identical PFGE type of MRSA from the couple and the infection was halted in the couple when the dog was treated completely for MRSA (Manian, 2003). Some reports implies that swine farmers are at risk of *S.aureus* and MRSA colonization (Armand-Lefevre et al., 2005; Voss et al., 2005). An attending pet surgeon who was an asymptomatic carrier of MRSA was found to be associated with postoperative wound infection of MRSA in five dogs (Leonard et al., 2006). In a survey conducted in a referral hospital for small animals from the nasal and oral mucosae of hospital staff and animals, MRSA was isolated from four dogs and 14 staff (Loeffler et al., 2005). The veterinary personnel working in veterinary hospitals are at greater risk of MRSA colonization and hence MRSA colonization is regarded as an occupational risk (Hanselman et al., 2006; Anderson et al., 2008; van Duijkeren et al., 2010; Jordan et al., 2011). MRSA colonized personnel plays a vital task in the MRSA introduction and transmission in veterinary health care settings (van Duijkeren et al., 2010; Sieber et al., 2011) and besides this they spread the infection to other persons (Anderson et al., 2008). An outbreak occurred at teaching veterinary hospital in Israel by an uncommon MRSA strain displayed the bidirectional spread between animal and humans (Schwaber et al., 2013). From animal health relevance methicillin-resistant *Staphylococcus pseudin-*

termedius (MRSP) is often associated with pyoderma and surgical site infections (Weese, 2008b) has swiftly emerging as an opportunistic nosocomial infectious agent (Laarhoven et al., 2011). MRSP can be detected in apparently normal animals (Murphy et al., 2009) and in veterinary hospital environment (Nienhoff et al., 2011). A large outbreak was recorded in Finnish veterinary teaching hospital caused by MRSP (Gronthal et al., 2014).

CLOSTRIDIUM DIFFICILE

Following the discovery of *C. difficile* in 1935, it was thought to be the normal faecal flora of the newborns rather than pathogenic (Hall and O'Toole, 1935). But the preamble of broad spectrum antibiotics prompted the emergence of pseudomembranous colitis and it is now considered one of the serious cause of nosocomial infections since it is emerging in the human community and food animals (Rupnik et al., 2009). *Clostridium difficile* is a gram positive, spore forming anaerobic bacterium. *C. difficile* spores are comparatively resistant to common disinfectants making *C. difficile* a lasting environmental contaminant. Many studies have reported a strong association between nosocomial *C. difficile* infection and antibiotic therapy in horses (Madewell et al., 1995; Ruby et al., 2009; Barr et al., 2013). In a Prospective study conducted in horses pre-treated with penicillin followed by experimental infection resulted in increased isolation of *C. difficile* from faecal samples, revealing the role of antimicrobials as a risk factor (Gustafsson et al., 2004). Prevalence and distribution of *C. difficile* was studied in dogs and cats visiting Veterinary Hospitals and animal shelters (Clouten et al., 2008; Schneeberg et al., 2012). A study conducted in an animal shelter in Germany, reported *C. difficile* prevalence rate of 5.5% and 3.5% in dogs and cats respectively further the study acknowledged that dogs and cats kept in animal shelters act as a reservoir for *C. difficile* PCR ribotypes that can infect human (Schneeberg et al., 2012). An another prospective study conducted in a veterinary teaching hospital reported that *C. difficile* could be isolated from 18% from dogs and cats and the study concluded that antibiotic administration prior to admission and administration of immunosuppressive drugs during hospitalization were risk factors for the nosocomial colonization (Clouten et al., 2008). *C. difficile* Ribotype 001, which is very common in hospitalized patients in Ontario was also frequently en-

countered among dogs in Ontario (Weese et al., 2010). A high environmental load of *C. difficile* is present in veterinary hospitals (Weese et al., 2000). An environmental survey conducted in a teaching veterinary hospital for the presence of *C. difficile* documented an isolation rate of 6.3%. The places where *C. difficile* was isolated are places of high animal traffic and rough floor (spores persist in cracks) with more likelihood of faecal contamination (Weese et al., 2000). Similar type of ribotype was reported from various species like in piglets (Keessen et al., 2013), calves (Costa et al., 2011), humans (Debast et al., 2009) and other food animals (Indra et al., 2009) and also in meat implicated in outbreaks (Rodriguez-Palacios et al., 2009). This paved way for making an assumption that *C. difficile* transmission from animals to human is likely to occur. An Austrian study concluded that animal reservoirs can be a possible source for human CDI infection through the food animals (Indra et al., 2009). However frank zoonosis was not established, owing to the ubiquitous nature of the organism it may act as common source for both animals and human beings.

MULTIDRUG-RESISTANT ESCHERICHIA COI AND OTHER ENTEROBACTERIACEAE

Multidrug-resistant nosocomial infections is one of the big challenges in tertiary-care veterinary hospitals and have turned out to be endemic in the veterinary hospital environment (Sanchez et al., 2002). Managing *E. coli* infections in veterinary hospitals has become more challenging task due to the emergence of multiple-antimicrobial-resistant *E. coli* in food animals and pet animals (Bischoff et al., 2001; Wagner et al., 2014; Zhao et al., 2001). The growing predominance of infections with organisms generating broad spectrum b-lactamses such as the ESBLs (mainly the CTX-M type), AmpC and carbapenemase enzymes are threatening the future of the b-lactam drug. Since b-lactams are inevitable to veterinary practice and the outlook of losing these drugs, warrants the necessity for defining the epidemiology of ESBL and carbapenemase producers in companion animals (Rubin et al., 2014). In the ICU of University of Georgia Veterinary Teaching Hospital, *E. coli* resistant to 12 antibiotics could be isolated from two dogs housed together, of which one dog died due to sudden septic shock. Followed by this incident 21 hospital-acquired *E. coli* infections were reviewed and found out that

the isolates had similar antibiotic resistance profiles (Sanchez et al., 2002). Mostly *E. coli* isolates of nosocomial events were found to be resistant to cephalosporins, beta lactams and beta lactamase inhibitor clavulanic acid and this attributes to a common *ampC* class of cephamycinases (Oteo et al., 2010). Especially, *ampC*-like gene, *bla*CMY2 was noticed in ceftriaxone-resistant *E. coli* isolates of animal origin (Zhao et al., 2001). Carriage of ESBL and AmpC-producing *E. coli* has been acknowledged in many species (Bortolaia et al., 2011). ESBL *E. coli* (O'Keefe et al., 2010) and AmpC producing *E. coli* (Oteo et al., 2010) are the emerging problems. ESBL *E. coli* are linked to range of clinical diseases like urinary tract infections, neonatal septicaemia and wound infections (Pitout, 2010; Ewers et al., 2014) and reported from canine clinical isolates (Sanchez et al., 2002; Shaheen et al., 2011). ESBL-producing uropathogenic *Escherichia coli* (CTX-M-15) were isolated from 5% dogs and 3.3% cats in Switzerland (Huber et al., 2013). A survey carried out in Netherlands in companion animals and horses demonstrated a 2% prevalence of ESBL and AmpC-producing isolates. The same study identified, ESBL producing *S. enterica*, *Proteus mirabilis* and *Enterobacter cloacae* from urinary, wound, respiratory, abdominal and bone infections (Dierikx et al., 2012). In Germany from six nosocomially infected dogs, OXA-48 type Carbapenemases producing *E. coli* and *K. pneumoniae* were isolated (Stolle et al., 2013) and in France CTX-M-15 generating *K. pneumoniae* have been detected from urinary tract infections of dogs and cats (Haenni et al., 2012). Clinical samples from urinary, wound infections etc. from Germany and European countries were investigated for ESBL producing *K. pneumoniae* from horses and companion animals. MLST and PFGE were performed for comparing with human isolates. About 75.8% of the strains possess ST15-CTX-M-15, which is a clonal group that emerged in humans in recent times and this strain shared PFGE clusters with human isolates, signifying the dissemination of this clonal group between human and animal populations (Ewers et al., 2014). There are reports of ESBL in other *Enterobacteriaceae* members like *Enterobacter* sp., *K. pneumoniae*, *Citrobacter* sp. and *Salmonella enterica* serovar Newport (Haenni et al., 2012; Ma et al., 2009). A recent study conducted in Netherlands reported a high prevalence of faecal carriage of *Enterobacteriaceae* resistant to third-generation cephalosporins in cats and dogs (Hordijk et al., 2013). Various risk-based case con-

trol studies reported that hospitalization is a major risk associated with the dogs to become multi-drug resistant (MDR) *E. coli* rectal carriers (Gibson et al., 2011; Hamilton et al., 2013). *Enterobacter cloacae*, also a nosocomial agent and particularly the multidrug resistant strains, are concerning (Wilberger et al., 2012).

ACINETOBACTER BAUMANNII

Acinetobacter spp. is environmental bacteria and normal flora of skin and mucous membrane in humans and animals and often associated with opportunistic infections in animals (Clemetson and Ward, 1990). *Acinetobacter baumannii* has emerged over the last decade as a cause of nosocomial infections and the pathogenicity is mainly due to multidrug resistance and biofilm formation. Its ability to acquire the resistance easily making it as one of the ominous agent to the existing antibiotic era (Kempf and Rolain, 2012). Outbreaks have been recorded in hospitalized animals (Francey et al., 2000) and associated with indwelling vascular catheter infection in horses (Vanechoutte et al., 2000). *A. baumannii* have been isolated from the clinical samples of companion animals (Francey et al., 2000; Zordan et al., 2011). It is evident that companion animals can be reservoirs of antimicrobial resistant bacteria and the role of pets in the dissemination of antimicrobial resistance is well understood (Guardabassi et al., 2004). The spread of multiresistant *A. baumannii* from a companion animal clinic to a horse clinic was recorded and the reason behind the transmission was believed to be the hands of staff personnel and students working simultaneously in both the clinics (Boerlin et al., 2001). Majority of the *Acinetobacter baumannii* isolates belong to ST25, where ST is an emergent clonal lineage which includes Carbapenemases including oxacillinases (OXA-58 and OXA-72), metallo- β -lactamases (NDM-1) (Zarrilli et al., 2013) and recently for the first time OXA-23 mediated Carbapenem resistance in sequence type 2 multidrug-resistant *Acinetobacter baumannii* was recorded from a cat with urinary tract infection. A recent study demonstrated increased resistance of *A. baumannii* towards desiccation and its biofilm forming ability on abiotic surfaces which facilitates its persistence in hospital environment (Giannouli et al. 2013), one more study revealed the isolation of carbapenem-resistant *A. baumannii* from hospital sewages in Beijing (Zhang et al., 2013). A multicentre cross-sectional study conducted to detect the carriage of *Acinetobacter baumannii* in pets revealed a carriage prevalence of

6.5% and nine carriers were identified from four veterinary clinics. Hospitalization and recent antibiotic therapy was notably associated with the carriage of *A. baumannii* (Belmonte et al., 2014).

MULTIDRUG-RESISTANT *ENTEROCOCCI*

Enterococci are saprophytic, Gram-positive, facultative anaerobes inhabiting the intestinal tract of humans and animals as a commensal. But now *Enterococci* has been emerged as an important nosocomial agent, particularly multiple drug resistance species of *Enterococci* (Poeta et al., 2006) and the development of multiple drug resistance among *Enterococci* species rose as a significant public health issue due to abuse and over exploitation of antibiotics in human and veterinary practices. It can also thrive well in dry hospital surfaces, medical instruments and resistant to heat, alcohol and chlorine (Fisher et al., 2009; Giraffa, 2002). In Europe *Enterococci* are ranked second most hazardous pathogen among intensive care unit-acquired bloodstream infections (Bohme et al., 2012). In the USA around 12% of the nosocomial infections are due to *Enterococcus* species. *E. faecalis* is the predominant species responsible for clinical infection whereas *E. faecium* claims the higher antibiotic resistance (Giraffa, 2002). Globally multiresistant *E. faecium* causing increasing number of hospital associated infections (Willems et al., 2012) and embodies upto to one third of Enterococcal infections (Willems and VanSchaik, 2009). In 1972, Vancomycin was first used and first vancomycin-resistant *Enterococci* (VRE) were documented 15 years later and NNIS accounted increase of 7.6% in Vancomycin resistant *Enterococci* between 1989 and 1993 (Metan et al., 2005). In a study conducted in Korea to investigate the possibility of MDR *Enterococcus* cross transmission, *Enterococcus* species was isolated from dogs, dog owners, veterinary personnel and five veterinary hospital environment and the study demonstrated a high prevalence of 62.5% of MDR *E. faecalis* and 75% of MDR *E. faecium* (Chung et al., 2014). In a study conducted in veterinary teaching hospital in Switzerland, two multiresistant *E. faecium* isolates with similar antibiotic resistant and PFGE profiles was recovered from two different cats with less than one month interval suggesting the persistence in hospital environment and nosocomial transmission (Boerlin et al., 2001). In the early 1980's the emergence of Hospital associated Ampicillin resistant *Enterococci* (ARE) in USA preceded rise of vancomycin resistance in *enterococci*, which happened

in the 1990s, is the reason why virtually all VRE of nosocomial infections in humans are also ampicillin resistant (Grayson et al., 1991) but ARE associated with human infections remain vancomycin susceptible (Tremblay et al., 2013). The hospital associated ARE have been recovered from dogs suffering from urinary tract infections in US (Simjee et al., 2002), Denmark (Damborg et al., 2009), Korea (Kwon et al., 2012) and also from the faeces of dogs departing the intensive care unit of an American veterinary medicine teaching hospital (Ghosh et al., 2011). In a study conducted in veterinary teaching hospital of Canada with the objective of characterizing the ARE strains of dogs and human revealed the cross-transmission between humans and dogs and further supports the significance of antibiotic stewardship to avoid zoonotic spread of canine ARE (Tremblay et al., 2013).

SALMONELLA

Salmonella enterica was found out to be a most common agent associated with nosocomial outbreaks in veterinary teaching hospitals through a survey conducted by the biosecurity experts (Benedict et al., 2008). Many outbreaks of nosocomial salmonellosis have been reported from different large animal hospitals especially among horses (Steneroden et al., 2010; Tillotson et al., 1997; Dallap et al., 2010; Schott et al., 2001). In horses *Salmonella* spp. can cause enterocolitis but the organism also present in the absence of the disease making the horse, a transient, sub-clinical shedders of *Salmonella* (Jones, 2008). Studies have reported 1% to 5% prevalence of the sub-clinical shedding of *Salmonella* by horses entering veterinary clinics (Roberts and O'Boyle, 1981). Persistence of *Salmonella* in the hospital environment has been often reported to be associated with nosocomial outbreaks (Steneroden et al., 2010; Schott et al., 2001) and environmental contamination with *S. enterica* in veterinary hospitals are identified as a hazard related to the nosocomial infections (Pandya et al., 2009; Ewart et al., 2001). In fact, many nosocomial outbreaks recorded in equine veterinary hospitals have been associated with multi drug resistant strains (Table 1).

MDR *Salmonella Typhimurium* have been reported from companion animals (Cherry et al., 2004; Low et al., 1996; Wall et al., 1996). In an outbreak occurred in a small animal hospital of US, two cats, one dog, 3 pet owners and two technicians were affected from a same strain of *Salmonella enterica* serovar *Typhi-*

Table 1: MDR *Salmonella* strains of nosocomial outbreaks in horses

Serial no.	MDR <i>Salmonella</i> strains of nosocomial outbreaks - Horses	References
1	<i>S. Infantis</i>	Tillotson et al., 1997; Dunowska et al., 2007
2	<i>S. Anatum</i>	Hartmann, 1995; Hartmann et al., 1996; Castor et al., 1989
3	<i>S. Heidelberg</i>	Amavisit et al., 2001
4	<i>S. Agona</i>	Donahue et al., 1986; Castor et al., 1989
5	<i>S. Krefeld</i>	Ikeda et al., 1985
6	<i>S. Saintpaul</i>	Ikeda et al., 1985; Hird et al., 1986
7	<i>S. Newport</i>	Castor et al., 1989; Dallap et al., 2010
8	<i>S. Oranienburg</i>	Kevin et al., 2014

murium (Cherry et al., 2004). A report documented multi-drug resistant *Salmonella Typhimurium* in four veterinary health care centres described that Pet care centres can act as a foci of *Salmonella* transmission between animals and humans, if necessary precautions are not followed (Wright et al., 2005).

OTHERS

Nosocomial transmission of *Cryptosporidium* was documented in a veterinary hospital through an outbreak involving multiple species, which originated from an infected dairy calf (Konkle et al., 1997). Biofilms are group of adherent microorganisms encased in a self-produced extracellular polymeric substance or slime, formed in both biotic and abiotic surfaces. They are often associated with a number of persistent infections that poorly respond to antibiotics (Hall-Stoodley, 2004). Nosocomial spread of *Mycobacterium bovis* between cats was recorded in a veterinary clinic in Ireland (Murray et al., 2014). In Hospital settings biofilm formation in indwelling medical devices like i.v catheter can harbour numerous potentially infectious pathogens resulting in elevated morbidity, mortality and propagation of antimicrobial resistance. The main pathogen for i.v catheter, urethral catheter and endotracheal tubes are coagulase negative *Staphylococci*, *E. coli* and enteric gram negative bacilli respectively. The other common pathogens forming biofilms are *S. aureus*, *K. pneumoniae*, *P. mirabilis*, *E. faecalis*, *P. aeruginosa*, *Streptococcus* spp, *Candida* spp (Lynch and Robertson, 2008). The nosocomial outbreak of canine parainfluenza infection was recorded in a veterinary referral hospital among dogs (Weese and Stull, 2013).

SURVEILLANCE IN VETERINARY HOSPITALS

Even though loads of recommendations for prevention and control of nosocomial infection is available out of the lesson learnt from previous experiences (Hartmann et al., 1996; Schott et al., 2001; Wright et al., 2005; Dallap et al., 2010; Goehring et al., 2010; Steneroden et al., 2010). Presently there is no recognized or published principles or standards for surveillance and control of infection in veterinary hospitals, which makes the system weak to determine rates and fraction of nosocomial and preventable infections respectively (Morley, 2002, 2004; Benedict et al., 2008; Morley and Weese, 2008).

The surveillance is broadly classified into Hospital wide surveillance and Targeted surveillance. The Hospital wide surveillance are very expensive, time consuming, laborious and tend to detect more infections which cannot be prevented (Pottinger et al., 1997). A study conducted for understanding the trends in nosocomial infections in University of Virginia Hospital for the period of eight years revealed that nosocomial infection rates are 4 times greater in intensive care units than in general wards (Landry et al., 1982), and during the study period there were seven infectious disease outbreaks and interestingly all the seven were in critical care units. One more study conducted on the same hospital exposed that the competence of surveillance systems for spotting nosocomial infection was maximum when it is focused in intensive care units rather than hospital wide surveillance (Wenzel et al., 1981). An additional study performed in German hospital exclusively in an intensive care unit revealed that only a minimum difference in the sensitivity and specificity when there is a targeted approach when compared to entire hospital wide sur-

veillance (Dettenkofer et al., 2001). By another study researcher found that narrowing the population under surveillance, like targeting the hospitalized patients with increased risk of developing nosocomial infections may increase the sensitivity and reduce the labour, money and time consumption (Brusaferro et al., 2006). Targeted surveillance is efficient and less time, money and labour consuming than hospital wide surveillance which requires more cost and effort for data collection (Morley, 2004). The only drawback of this approach is missing out of nosocomial infections in general ward and other area patients.

DIFFERENT METHODS OF TARGETED SURVEILLANCE

- Device associated infection surveillance
- Specific etiological agent surveillance
- Syndromie based surveillance
- Environmental based surveillance
- Laboratory based surveillance

DEVICE ASSOCIATED INFECTION SURVEILLANCE

Most of the device associated infections that had been published are restricted to dogs with urinary catheter (Wise et al., 1990). A prospective study done with 18 male cats to evaluate the incidence of catheter-associated urinary tract infections by collecting urine samples three times, i.e. straight away after catheterization, 24 hours after and before removal. The bacterial culture of the urine samples detected that six cats (33.3%) developed bacteriuria, 5 cats with *Escherichia coli*, *Staphylococcus* species, one cat with *Streptococcus bovis* and one more cat developed fungal infection (Hugonnard et al., 2013). A prospective study conducted by Smarick and others in 2004 reported 10.3% of healthy catheterized dogs of both sex developed urinary tract infection. Furthermore this study revealed that female dogs are more susceptible to develop the urinary tract infection (Smarick et al., 2004). A randomized clinical trial was performed with dogs underwent intervertebral disk correction surgery. Based on sex, the dogs were stratified and assigned randomly with three different urinary bladder managing methods, viz. manual expulsion, intermittent catheterization or catheter insitu. The proportion of urinary tract infection was higher in dogs with indwelling catheter and 32% showed noticeable growth of minimum one bacterial species (Bubenik and Hosgood, 2008). The other device always associated with nosocomial infection in animal is intravenous catheter (Marsh-

Ng et al., 2007) and it is due to the contamination of the catheter (Johnson, 2002). Number of studies have been conducted to estimate the prevalence of contamination of intravenous catheter in veterinary hospitals. In a study conducted for one year period at intensive care unit Ontario Veterinary College, they collected all the intravenous catheters from dogs and cats and cultured and found out the bacterial contamination rate of 10.7% (Mathews et al., 1996). With another study the bacterial contamination rate of intravenous catheter from 100 dogs was found out to be 22% and the bacteria isolated were often found to be of gastrointestinal and environmental origin (Lobetti et al., 2002). Other studies reported 24.5% (Marsh-Ng et al., 2007) and 23.2% (Jones et al., 2009) of bacterial contamination rates due to intravenous catheters in dogs and cats.

SPECIFIC ETIOLOGICAL AGENT SURVEILLANCE

Some hospitals are performing surveillance based on specific etiological agents which are associated with nosocomial infections. In 2008, Benedict et al. (2008) conducted a study in US veterinary teaching hospitals and reported that 53% of hospitals are collecting samples for detecting the specific pathogen and it is their one of the element of infection control practices. One of the specific contagious pathogen often encountered in veterinary nosocomial outbreaks and also incorporated in hospital surveillance is *Salmonella* (Schott et al., 2001; Cherry et al., 2004; Benedict et al., 2008; Steneroden et al., 2010). Patient who are under greater risk of shedding *Salmonella* are included in the surveillance (Morley, 2002, 2004; Morley and Weese, 2008; Ekiri et al., 2010). The sampling plan includes faecal sampling at the time of admittance and then at regular intervals during the hospital stay (Morley, 2002; Ekiri et al., 2010). If *Salmonella* was not present at the time of admittance and detected during subsequent sampling, which of similar serotype and antibiogram pattern as other isolates in the patients, then the Salmonellosis is considered to be of nosocomial origin (Ekiri et al., 2010). A study conducted for *Salmonella* surveillance in 246 hospitalized colic horses reported positive result in 9% of the faecal sample (Kim et al., 2001). In Human medicine one of the most significant nosocomial pathogen is Methicillin-resistant *Staphylococcus aureus* (MRSA) and in all probability it is one of the emerging multiple drug resistant bacteria in veterinary health settings (Beard, 2010). In a survey conducted in seven teaching veteri-

nary hospitals in the United States regarding the *S. aureus* isolated from hospitalized patients revealed that 14% of animals were infected with Methicillin-resistant *Staphylococcus aureus* and the highest prevalence was estimated in horses and dogs (Middleton et al., 2005). In an attempt to determine the prevalence rate of MRSA, an emerging equine pathogen, a screening program was organized, in which nasal swab was collected from all horses during admission, hospitalization and discharge. MRSA was isolated from 5.3% of horses and the incidence rate of overall nosocomial MRSA was found to be 23/1000 admissions (Weese et al., 2006b). A study conducted in a small animal hospital revealed MRSA prevalence of 9% in dogs (Loeffler et al., 2005). Various studies have also documented clear rise in the MRSA infections on surgical sites of companion animals (Boag et al., 2004; O'Mahony et al., 2005). A retrospective study with the faecal culture data conducted in a teaching veterinary hospital following an outbreak of salmonellosis with high percentage of cases within 24 hours of admission revealed the etiological agent was *Salmonella enterica* serovar Oranienburg. Severe scrutiny of their medical records exposed the concealed epidemiological association to the veterinary hospital following the index case (Cummings et al., 2014).

SYNDROME BASED SURVEILLANCE

Syndrome based surveillance means detecting simple adverse conditions (pyrexia of unknown origin) in hospitalized patients or distinct signs and symptoms of any infection (Mostashari and Hartman, 2003). This system can be used based on the monitoring of clinical data (flu-like symptoms) and nonclinical data (sale of over-the-counter drugs or school absenteeism) (Lombardo et al., 2003; Mostashari and Hartman, 2003). On an added advantage, to make an evidence-based veterinary practices, the Syndromic surveillance in veterinary hospitals can be used concurrently to collect information about prevalence, incidence and various risk factors prevailing in the animal population (Stone and Hautala, 2008). Various studies have been conducted with syndromic surveillance in veterinary hospitals (Nicholson et al., 2002; Eugster et al., 2004; Ahern et al., 2010; Ruple-Czerniak et al., 2014). A syndromic surveillance for evaluating the occurrence of healthcare-associated infections in Critical Care Units of Small Animal Referral Hospitals reported that 16.3% of dogs and 12% of cats had ≥ 1 nosocomial syndrome during hospitalization

(Ruple-Czerniak et al., 2013). Another Syndromic surveillance used to estimate the rate of nosocomial infections in equine hospitals reported that 19.7% of the study population had at least one nosocomial event during hospital stay and the most commonly observed nosocomial syndromes were surgical site inflammation and intra-venous catheter site inflammation (Ruple-Czerniak et al., 2014). Though the specificity of this system is low in outbreak surveillance, the sensitivity is high by guaranteeing the pertinent markers of disease (Van Metre et al., 2009). Some of the relevant markers used in the surveillance are:

Acute respiratory tract disorders: evidence of coughing, abnormal lung sounds, dyspnoea or tachypnea, sneezing, nasal discharges.

Acute infectious gastrointestinal disorders: diarrhoea, vomiting, abdominal pain or discomfort.

Pyrexia of unknown origin: temperature more than 102.0°F in horses or more than 102.5°F in dogs and cats.

Septicemia: clinical or microbiological confirmation of septicemia

Surgical wound analysis: inflammation, infection or discharges.

ENVIRONMENTAL BASED SURVEILLANCE

In Environment based surveillance the hospital should submit the hospital environment sample for routine culture. Many studies have been published stating that hospital equipment and fomites harbouring potential nosocomial infectious agents and act as a reservoir such as sponge pots with benzalkonium chloride (Fox et al., 1981), stethoscopes (Fujita et al., 2013), thermometers (Van den Berg et al., 2000; Weese et al., 2000), Faucet handles and computer keyboards (Bures et al., 2000), endoscopes (Schelenz and French, 2000; Cowen, 2001), multiple-dose vials (Sabino and Weese, 2006), Cellular phones (Brady et al., 2007; Julian et al., 2012), white coats and surgical scrubs (Singh et al., 2013). Examination tables, floors and doors (van Balen et al., 2013). In 2004, Burgess et al., reported that the nosocomial infectious agents are often encountered in the environment whenever the nosocomial rates are increased (Burgess et al., 2004). And it has been reported that contamination of veter

Table 2: Percentage recovery of nosocomial agents in environmental survey of hospitals

S.no	Nosocomial agent	Percentage recovery in environmental survey of hospitals	Reference
1	<i>Salmonella</i> spp	2.1%	(Alinovi et al., 2003)
2	<i>Salmonella</i> spp	11.9%	(Burgess et al., 2004)
3	<i>Clostridium difficile</i>	6.3%	(Weese et al., 2000)
4	MRSA	9.6%	(Weese et al., 2004)
5	<i>Staphylococci</i> count	55.9% of sample contain ≥ 2.5 cfu/cm ²	(Aksoy et al., 2010).

inary hospital environment was responsible for many nosocomial infection outbreaks (Castor et al., 1989; Hartmann et al., 1996; Tillotson et al., 1997; Schott et al., 2001; Weese and Armstrong, 2003; Wright et al., 2005; Dallap et al., 2010; Steneroden et al., 2010). The percentage recovery of nosocomial agents in environmental survey of hospitals is depicted in table 2.

LABORATORY BASED SURVEILLANCE

The Surveillance system used in human health care centres includes laboratory diagnosis (Emori and Gaynes, 1993; Brossette et al., 2006). Many researchers in veterinary nosocomial infections also included laboratory diagnosis for confirmation (Biertuempfel et al., 1981; Mathews et al., 1996; Lobetti et al., 2002; Smarick et al., 2004; Marsh-Ng et al., 2007; Bubenik and Hosgood, 2008; Jones et al., 2009) and some researchers have not included laboratory confirmation (Nicholson, 2002; Eugster et al., 2004; Ahern et al., 2010). Committing laboratory confirmation is not cost effective and also more time consuming which prevents immediate action during outbreaks. In other way laboratory diagnosis can be used as a passive surveillance in regular basis. Passive surveillance means collecting data for other purposes, like samples which are regularly collected from patients can be tested for nosocomial infectious agents and Active surveillance means data collection for the specific purpose, and these are the types based on data collection (Morley, 2004). But the sensitivity of active surveillance is greater than the passive surveillance (Brachman, 1993).

METHODS IN DATA COLLECTION AND COMPARISON

The data collection may be either Prospective or Retrospective. Data collection by monitoring the patient during hospitalization is Prospective and data collection by reviewing the hospital records after the pa-

tient has been discharged is Retrospective (Abrutyn and Talbot, 1987). Eventhough the Prospective data collection is gold standard there is a possibility of missing out of nosocomial infections after the patient is discharged (Freeman and McGowan, 1981) however it is wise to follow prospective surveillance during outbreaks of nosocomial infections (Wenzel et al., 1976). But retrospective method is used in hospital readmissions for infections (Pottinger et al., 1997). Lot of studies has been conducted to illustrate the magnitude of nosocomial infections occurring after discharge from hospitals especially post-surgical infections (Brown et al., 1987; Delgado-Rodriguez et al., 2001; Eugster et al., 2004). There are two methods in prospective data collection i.e patient-based collection methods by nurse or physician while attending the patient (Abrutyn and Talbot, 1987; Pottinger et al., 1997) and diagnostic laboratory-based data collection which is time consuming, lacking in clinical data and with more false positive and false negatives (Abrutyn and Talbot, 1987).

Inter-hospital comparison of data of nosocomial infections will facilitate the effective surveillance and for this nosocomial infection rates should be determined in each hospital (Gaynes, 1997). But the crude rates cannot be compared since it varies with the patient number, hospital size, facilities, case load, underlying illness and severity of disease (Pottinger et al., 1997; Sax et al., 2002). For effective comparison it must be standardized like, which risk factors should be taken into account like length of hospital stay, exposure to invasive devices and intrinsic factors of patient (Pottinger et al., 1997).

PREVENTION AND CONTROL OF NOSOCOMIAL INFECTIONS: BEST TO BE PROACTIVE RATHER THAN REACTIVE

- Hand hygiene is the easiest, cost effective and most underused measure (Sax et al., 2007). Hand washing with plain soaps failed to remove pathogens (Ehrenkranz et al., 1991) and also there are ironical reports stating that hand washing with plain soaps increases the bacterial counts on the skin (Larson et al., 1986; Winnefeld et al., 2000). Proper hand hygiene (Sax et al., 2007) and 70% alcohol gel based hand sanitizers should be placed throughout the hospitals (Kampf et al., 2002; Leonard et al., 2008). The alcohol based hand sanitizers have increased antimicrobial activity and reduces the cross contamination from taps and paper towel dispensers (Harrison et al., 2003). Hand washing should be done– i) before and after contact with a patient, ii) before and after contact with objects in the animals environment, iii) after contact with potentially infective biological specimen or discharges and iv) before and after wearing gloves is necessary (CCAR, 2008).
- Preliminary screening of all patients for signs of contagious disease before admission to the hospital and separate isolation facility for the contagious disease infected animals (Traub-Dargatz et al., 2004).
- If environmental contamination is suspected, regular monitoring and intervention is required with periodic spot checks of environment (Traub-Dargatz et al., 2004).
- Veterinary health care personnel should take necessary occupational health measures like personal protective equipment, vaccination while handling infected materials like discharges, blood and sharps (Mielke, 2010).
- The outerwear should be changed frequently since gross contamination does not need for pathogen to be present and attached laundry services may be provided.
- Cover skin lesions and open wounds. Strict asepsis in surgery with autoclaved surgical instruments and thoroughly cleaned endotracheal tubes (CCAR, 2008).
- Removal of implants and appropriate antibiotic treatment based on antibiogram (Leonard et al., 2006).
- Animals with suspected clinical signs of any infectious diseases should not be admitted for any elective procedures (CCAR, 2008).
- Animals belonging to hospital workers should be screened (Leonard et al., 2008)
- Animals with multi-drug resistant infections should be handled with great precautions since the body sites like nose, rectum could be colonized with those pathogens (CCAR, 2008).
- Ensure appropriate handling of sterile medical devices particularly indwelling devices like urinary catheter and drugs for parental administration. Invasive procedures should only be performed if mandatory.
- Regular collection of Laboratory samples as a part of comprehensive monitoring programme. For example, Faeces can be collected for culture to detect salmonella from all the animals admitted for colic. If a particular nosocomial agent has been a problem in the past, there should be a readymade programmed action plan (Traub-Dargatz et al., 2004).
- Special precautions on re-dispensation of medical products by proper disinfection and sterilization and disinfection of hand touch surfaces. Touching clean items like telephone or microscope while handling potential infectious material like swabs should be avoided.
- Ensure healthy patient environment and waste disposal (Mielke, 2010).
- Monitoring of antibiotic drugs consumption and development of resistance. Ensure antibiotic stewardship.
- Adequate education and training for staff on infection control and occupational health supervision and Education of veterinary graduates and personnel about nosocomial infections and the significance of infection control measures (Schwaber et al., 2013).
- Client education particularly about zoonosis if the veterinarian has a reasonable suspicion of any zoonotic infectious disease.
- The surveillance of nosocomial infections should be accomplished by creating nationwide reference data which will facilitate the quick reporting about infection clusters, outbreak and thereby makes evidence based preventive and control measures (Mielke, 2010).

Nosocomial infections are preventable yet it is more neglected area of veterinary practice since it warrants some added tasks which do not fetch money. Unfortunately it will influence the success of the treatment and care provided so it cannot be ignored any longer. The mandate elements for providing patient safety and to prevent nosocomial infections are clean hospital environment, clean equipment and clean procedures or practices. Further in broader sense proactive policies, health worker education, safe use of medicines and surveillance system can strengthen patient safety, curtail dissemination of antibiotic resistance and zoonotic diseases.

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