External ventricular drain infections: successful implementation of strategies to reduce infection rate

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INTRODUCTION External ventricular drain (EVD) infections can cause serious complications. We performed an audit of EVD infections within our neurosurgical unit. Through this study, we aimed to reduce the incidence of external ventricular drain-related infection, including ventriculities in neurosurgical patients.

METHODS We conducted an audit of the EVD infections in our institution observed over a one-and-a-half year period. This was conducted in three phases. A baseline EVD infection rate was determined for Phase I, from January to June 2007. We introduced the following measures to reduce EVD infection rate in Phase II, from July to December 2007: (1) For Neurosurgery doctors: performing proper surgical techniques to minimise intra-operative infections; educating junior doctors on proper CSF sampling from the EVD; and minimising the number of days the EVD is maintained *in situ*; (2) For Neurosurgery nurse clinicians: developing Standard Operating Procedures on nursing management of EVDs; conducting EVD care workshops for nurses working in neurosurgical wards; and competency skill checks on the management of EVDs for nurses working in the neurosurgical wards. Silver-coated EVDs were introduced in Phase III of the study from January to June 2008.

RESULTS The EVD infection rate decreased from a baseline of 6.1% to 3.8% in Phase II; a further reduction from 3.8% to 0% was achieved during Phase III.

CONCLUSION Good teamwork among doctors and nurses is essential for reducing EVD infection rate. We managed to reduce EVD infections substantially and would continue to strive to remain infection-free in the future.

Keywords: cerebrospinal fluid, external ventricular drain, infection
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INTRODUCTION

One of the most frequently encountered problems in a neurosurgery unit is hydrocephalus, which can occur in a number of different clinical situations, including intracranial haemorrhage, spontaneous subarachnoid haemorrhage and intraventricular haemorrhage. External ventricular drain (EVD) is used for temporary diversion of cerebrospinal fluid (CSF) in acute hydrocephalus. EVD also provides a means of monitoring and controlling elevated intracranial pressure (ICP), especially in head trauma. In fact, EVD is the gold standard for ICP monitoring. Insertion of an EVD is perhaps one of the most common neurosurgical procedures performed worldwide. However, patients with these surgically implanted foreign bodies are at risk of developing drain-related infections such as ventriculitis and meningitis, which may result in significant morbidity and even mortality if not treated appropriately. Re-siting a new EVD and prolonged hospital stays with antibiotic treatment are some of the possible consequences of an EVD infection,[1] leading to higher healthcare costs not only for the patients but also for the hospital system.

The reported incidence of EVD infections in the current literature is wide ranging, with rates ranging from 2% to as high as 27%,[2,3] which is a significant health concern. A reduction in EVD infections would certainly shorten the duration of hospitalisation and reduce costs for patients.

Many factors are involved in EVD-related CSF infections (Fig. 1). We present the results of a completed audit loop following the introduction of evidence-based protocols for EVD insertion and its subsequent management. By adhering to these protocols, we were able to significantly reduce the EVD infection rate in our neurosurgical unit. We hope that other units will benefit from our experience in their efforts to reduce the EVD infection rate in their respective institutions.

METHODS

We performed an audit loop of EVD infections at our institution over a one-and-a-half year period. The audit cycle consisted of three phases, with each phase lasting six months. We collected the data of patients who had EVDs inserted during the entire study period and examined the EVD infection rates in each phase. Paediatric patients were excluded from the study. An EVD-related CSF infection was defined as catheter-associated meningoventriculitis confirmed by a positive CSF culture.[2] Several studies mandate the presence of CSF pleocytosis, a high protein level or low glucose level, in addition to a positive CSF culture.[4] As a standard practice in our unit, we only sampled patients with EVDs who developed signs of sepsis. CSF cultures were repeated if the initial results were positive, so as to rule out the possibility of contaminants in the initial positive cultures.

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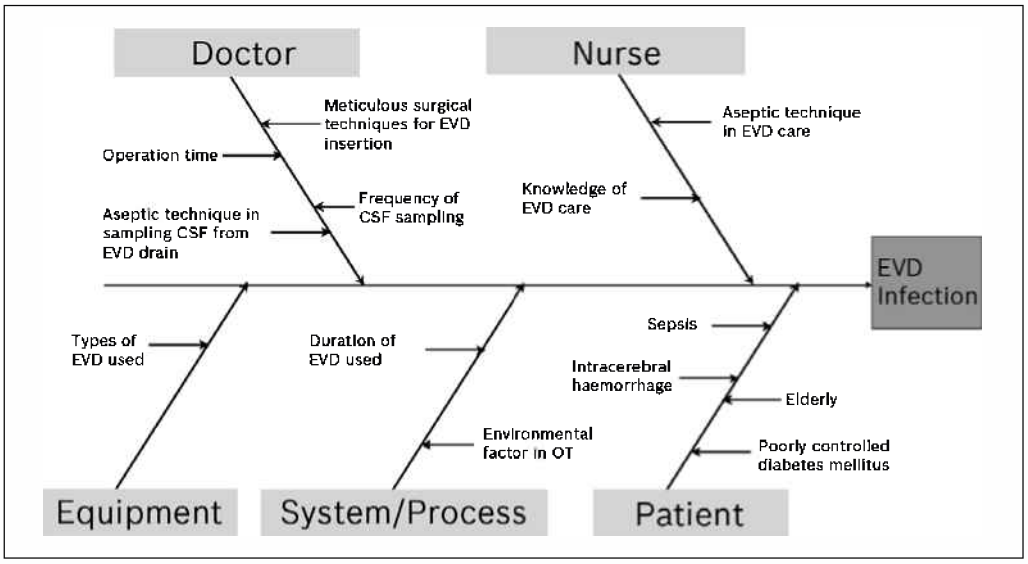

Fig. 1 Cause and effect diagram for external ventricular drain infection.

Other sources of sepsis, e.g. chest or urinary tract infections, were eliminated by performing the necessary blood tests, cultures and imaging studies. Thus, only septic patients with CSF-positive cultures were deemed to have EVD-related CSF infections.

Phase I of the audit was conducted from January 2007 to June 2007. This phase entailed a retrospective review of our institution's EVD-related infection rates before the introduction of any measures. Phase II was conducted from July 2007 to December 2007, and involved a retrospective review of the infection rates. This period of review was subsequent to the introduction of protocols for EVD insertion and subsequent management of EVDs, which were targeted at the neurosurgeons performing the surgery, the doctors directly involved in the daily care of patients with EVDs and the nurses treating these neurosurgical patients. Phase III of the audit was conducted from January 2008 to July 2008. This was a prospective audit following the introduction of silver nanoparticle-impregnated EVD catheters, and evaluated whether the use of these catheters would further lower EVD-related infections in our unit. Data analysis was performed for all three phases. Fisher's exact test was applied to determine the significance of EVD infection rates, and a p-value < 0.05 was considered statistically significant.

During Phase II, meticulous surgical techniques to minimise intra-operative infections were introduced (e.g. enforced hand washing for at least two minutes, limiting the number of personnel in the operating theatre and minimising the duration of the operation). The chief neurosurgical registrar trained the junior neurosurgical ward doctors on strict aseptic techniques for sampling CSF, which was performed only when an EVD infection was suspected. The sampling was done after proper hand washing and using sterile pre-packed disposable culture sets. The ports from which the CSF was collected were also thoroughly cleaned with antiseptic solution before the sampling. We also minimised the number of days the EVD was maintained *in situ*. If longer periods of CSF diversion were required, the EVD was changed. EVD exchange, performed within ten days after the initial EVD insertion, was done through the same burr hole. A nurse clinician in the neurosurgical unit developed a set of Standard Operating Procedures (SOP) on the nursing management of patients with EVDs and conducted an EVD care workshop for all nurses from the neurosurgical wards in order to instruct them on proper EVD care. As a follow-up to the EVD care workshop, competency skill checks were performed for the neurosurgical ward nurses.

Table I. A 2 × 2 contingency table of the number of patients with EVD-related CSF infections in study Phases I and III.

Study phase	No. of patients (%)		Total
	Infection	No infection	
Phase I	5 (6.1)	77 (93.9)	82
Phase III	0 (0)	73 (100)	73

Data was analysed by Fisher's exact test (p = 0.039).

RESULTS

The total sample size of the study was 234 patients, of which 152 were male and 82 were female. The patients were aged 31–69 years. No paediatric patient was included in the study. The number of patients who underwent EVD insertions in each phase were almost similar (range 73–82 patients). There was also no difference in the demographics and indications for EVD insertion in all three phases. In Phase I, five out of 82 patients developed EVD infections (6.1%). The average duration that the EVDs were maintained *in situ* was 8.6 days. Following the institution of the new protocols in Phase II, the EVD infection rate was reduced to 3.8% (three out of 79 patients). The average duration of EVDs *in situ* was also reduced to 7.4 days. At Phase III, following the introduction of silver nanoparticle-impregnated EVDs, we saw a further reduction in the infection rate from 3.8% to 0.0% (0 out of 73 patients).

Of the eight patients with EVD infections in Phases I and II, *Staphylococcus aureus* (*S. aureus*) was isolated from the CSF cultures of three patients, two of which were of the methicillin-resistant type. Other isolates cultured from the CSF samples included *Acinetobacter* (n = 3), *Enterobacter cloacae* (n = 1) and

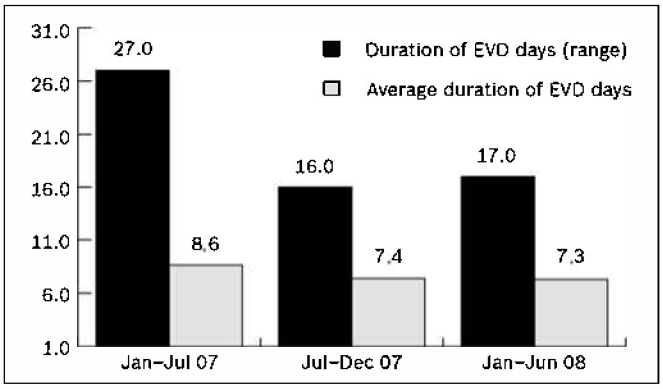

Fig. 2 Graph shows the mean external ventricular drain duration in each study phase.

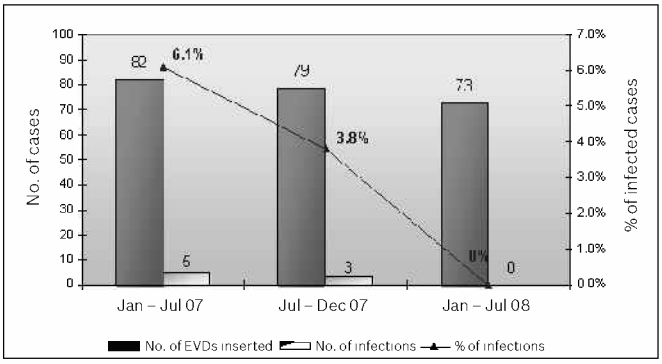

Fig. 3 Graph shows the number of patients in which external ventricular drain (EVD) was inserted and the number of EVD infections in each phase.

Candida parapsilosis (n = 1). The average duration of EVD usage in Phase III was 7.3 days (Figs. 2 & 3). Although the duration that the EVD remained *in situ* differed in each phase with a trend toward a shorter duration, this difference was not statistically significant. The EVD-related infection rate of 6.1% in Phase I vs. 0% in Phase III was statistically significant (p = 0.039) (Table I).

DISCUSSION

Hydrocephalus is a common neurosurgical problem worldwide. It often arises as a result of an obstruction of CSF flow, and EVDs serve as an alternative outlet flow for CSF. This provides a control for the possible elevation of ICP resulting from obstructed CSF flow. Since EVD insertion acts as a temporary diversion of CSF, it is one of the most common neurosurgical procedures performed. Insertion of an EVD is a simple procedure that can be performed in a relatively short time. Bacterial colonisation of surgical implants, including EVD catheters, is common and does not necessarily indicate an infection of the catheter.[5] In fact, confirmation of EVD-related infection requires a combination of appropriate clinical manifestations, including symptoms and signs of meningism, together with positive CSF cultures.[6] However, bacterial colonisation of the EVD catheter with subsequent retrograde infection resulting in meningoventriculitis is a distinctly possible complication of any inserted EVD.[7] Although the incidence of CSF infections resulting from the presence of an EVD catheter varies, it has been reported to be as high as 27%.[2,3]

The medical and economic effects of infection are potentially severe. Prolonged hospitalisation and the extended use of intravenous antibiotics to treat infections or even uncontrolled sepsis leading to death are significant complications of EVD-related infections. Morbidity, and even mortality, as a consequence of a severe EVD-related infection could be significantly reduced if the infection rates can be substantially reduced. Hence, due to the severe complications that could arise despite the simplicity of the procedure, we conducted this audit cycle at our institution to determine whether the introduction of simple protocol measures and the use of silver-impregnated catheters would reduce infection rates.

The patient demographics, indications for EVD insertion and duration of EVD *in situ* were similar in each study phase. The protocols introduced in Phase II, which targeted clinicians at all levels and attending nurses, significantly reduced the EVD infection rate from 6.1% to 3.8%. It has been widely established that meticulous surgical techniques remain one of the most important variables in reducing shunt infection.[8] As avoidance of wound haematoma and careful manipulation of tissues contribute to the reduction in infection rates, this approach was one of the strategies employed and consistently enforced in the final two phases of the study. The duration of surgical hand washing has also been reported to have an impact on surgical infection. In Tanner's review of surgical hand antisepsis, it was found that a two-minute surgical scrub is sufficient[9] to reduce the incidence of infections. Thus, a minimum duration of at least two minutes was enforced for surgical hand washing for every person involved in the surgery.

Based on Hoefnagel et al's study, a higher frequency of CSF sampling and a longer duration of catheter use were associated with EVD infection.[10] Thus, the EVD catheter should be electively changed whenever a longer duration of CSF drainage is required. For our protocol, EVD exchange was performed within ten days of the initial EVD insertion and through the same burr hole. In our study, the average duration of EVD *in situ* was reduced from 8.6 days in Phase I to 7.4 days in Phase II, and finally to 7.3 days in Phase III. This could have contributed to a reduction in the infection rate in each phase. However, there is conflicting evidence in the reported literature. Lo et al[11] found that EVD-related infections were independent of drain duration and that the insertion of multiple EVDs in previously uninfected patients was a significant risk factor for developing an EVD-related CSF infection.[11] Therefore, whether EVD exchanges would lead to a decrease in CSF infection rates is still controversial. A larger prospective study to address this question would certainly be of great clinical importance and interest.

The standard practice in many neurosurgical units is to include CSF sampling of the patients' EVDs only when there is clinical suspicion of a CSF infection,[10] i.e. fever of unknown origin, nuchal rigidity, headache, mental status changes, cranial nerve symptoms and/or peripheral leucocytosis not related to other infections. This practice is in keeping with the reported increased infection rates associated with more frequent CSF

Table II. Microbiology of EVD-related CSF infections.[7]

Aetiological agent	Incidence (%)
Staphylococcus epidermidis	70
Staphylococcus aureus	10
Others (including Gram-negative bacillus and fungi)	< 20

sampling.[10] Thus, protocols regarding CSF sampling were strictly enforced during Phases II and III of the study. In addition, we felt that the protocols should not only be targeted at attending doctors but also the attending nurses, and this joint targeting played an integral part in reducing EVD infections in our unit. Woodward et al, who proposed in their review that sharing good practices could help to prevent repetition of effort by nurses engaged within the same specialty,[5] have developed guidelines and shared these evidence-based practices through the Pan London Neuroscience Development Forum. Similarly, our nurse clinician also conducted EVD care workshops for the continuing education of the nurses, in line with the unit's goal of reducing the EVD-related infection rate. Only the coordinated efforts of all involved in the care of these patients would result in a difference.

The microbiology of EVD-related CSF infections reported in the literature is depicted in Table II.[7] Although the most frequently reported and isolated bacteria in EVD-related CSF infections is *Staphylococcus epidermidis*,[12,13] the profile of aetiological agents cultured can differ between institutions. Lo et al, who reported that *Acinetobacter* infections comprised almost half of their cases,[11] attributed these infections to an outbreak of *Acinetobacter* during the time of their study. Data collected on the specific microbiology of the organisms cultured in our study revealed that *S. aureus* and *Acinetobacter* were the most commonly isolated agents. However, due to the small number of infections in our study, this may not be representative of the most commonly isolated aetiological agents. It is, however, interesting to note that the spectrum and profile of bacterial infections, including sensitivities to subsequent antimicrobial therapy, may differ between neurosurgical units, depending on the usage of antibiotics in each institution. The design of future studies should include this aspect so as to provide more meaningful clinical evidence for practising clinicians.

Although the efficacy of silver as an anti-infection agent has been established, its mode of action has not been clearly elucidated.[14] Published data has shown that silver nanoparticle-impregnated EVD catheters were effective in reducing the risk of EVD infection.[15] In fact, a recent large randomised study – the Silver-Impregnated Line Versus EVD Randomised (SILVER) Trial, which examined the effectiveness of silver-impregnated EVDs against the development of EVD-related infection, has found a reduction in infection rate from 16.9% to 12.3%.[16] This trial has provided Class I evidence that silver-impregnated EVDs reduce EVD-related infections. Following the introduction of silver-impregnated EVDs in Phase III of our study, we also saw a further reduction in the infection rates, suggesting that silver-impregnated EVDs are effective for reducing infection. Our institution's experience in Phase III is similar to Keong et al's final results.[16] Our audit review of Phase III showed an infection rate of 0.0%; although these results are preliminary, we hope to conduct a larger study to confirm our findings.

There are some limitations in our study. First, Phases I and II of the study were retrospective reviews, and thus selection bias and missing data may potentially compromise the review. Second, our study population was small, consisting of only 234 patients that were further subdivided into the three different phases. The six-month duration of each phase was another shortcoming of the review, which resulted in an even smaller number of patients within each phase. Therefore, although the study demonstrated a statistically significant reduction in EVD infection rate from Phase I to III, the small study may not have been powerful enough to detect the utility of these measures. Despite these limitations, the measures introduced should not be discounted. A larger future study that takes into account the sample size, i.e. recruits more patients in each phase and has a longer study period within each phase, would certainly be useful in resolving some of the shortcomings of the current study. Our present audit serves as a preliminary step toward achieving this aim of conducting a larger study.

Institutions differ from each other in terms of their practice and protocols. Although these differences are subtle, each institution must take them into account and make necessary changes based on their individual practices. Therefore, our experience may not be applicable to all institutions. It does, however, form a guide for others to individualise their protocols to match their own unique clinical setting.

The combined and co-ordinated efforts of the surgeons, ward doctors and nursing staff, together with the use of silver nanoparticle-impregnated EVD catheters, have resulted in our success in reducing EVD infection rate in our institution to 0.0% during the last phase of the study. We will continue to strive to maintain as low an infection rate as possible, if not remain infection-free, by adhering closely to these proven protocols. Due to our small study population, we hope that a larger future study will confirm the utility of the efficacy of the measures in reducing EVD-related CSF infections.

Finally, we would like to reiterate that our measures serve only as a guide, and since each institution's practices may vary, protocols must be tailored accordingly. However, we hope that sharing our experience will help other institutions replicate our success by individualising their own protocols so as to reduce significantly, if not eliminate completely, EVD-related CSF infections in their institutions.

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