Risk factors for surgical site infections in neurosurgery

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ABSTRACT

INTRODUCTION Surgical site infections (SSIs) are of profound significance in neurosurgical departments, resulting in high morbidity and mortality. There are limited public data regarding the incidence of SSIs in neurosurgery. The aim of this study was to determine the rate of SSIs (particularly those requiring reoperation) over a seven-year period and identify factors leading to an increased risk.

METHODS An age matched retrospective analysis was undertaken of a series of 16,513 patients at a single centre. All patients who required reoperation for suspected SSIs within a 7-year period were identified. Exclusion criteria comprised absence of infective material intraoperatively and patients presenting with primary infections. Clinical notes were reviewed to confirm presence or absence of suspected risk factors.

RESULTS Of the 16,513 patients in the study, 1.20% required at least one further operation to treat a SSI. Wound leak (odds ratio [OR]: 27.41), dexamethasone use (OR: 3.55), instrumentation (OR: 2.74) and operative duration >180 minutes (OR: 1.85) were statistically significant risk factors for reoperation.

CONCLUSIONS This is the first UK study of such a duration that has documented a SSI reoperation rate in a cohort of this size. Various risk factors are associated with the development of SSIs, making it essential to have robust auditing and monitoring of high risk patients to ensure excellent standards of healthcare. Departmental and public registers to record all SSIs may be beneficial, particularly for those treated solely by general practitioners, allowing units to address potential risk factors prior to surgical intervention.

KEYWORDS

Surgical site infection – Wound infection – Risk factors – Wound leak

Accepted 2 June 2018

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Surgical site infections (SSIs) are of profound significance in a healthcare setting, both in terms of patient outcomes and healthcare costs. SSI rates have been described in the literature as accounting for 1.1–19.78% of all healthcare associated infections¹ and they create an additional cost to the National Health Service (NHS) of £2,100–£10,500 per infected case.² The need for further surgical intervention to treat SSIs increases this cost owing to extended postoperative hospital stays, prolonged intravenous antibiotic treatment, delayed wound healing and extended inpatient rehabilitation times. There are many published studies looking at SSI rates and associated risk factors but it is difficult to compare these studies because of the lack of homogeneity with respect to the definition of SSIs and follow-up duration.

In 2004 Patient Health England implemented a SSI surveillance service for orthopaedic surgery. This was later extended to a range of other surgical fields, including cranial and spinal surgery. Using this service, the five-year SSI

rate for cranial and spinal surgery was estimated at 1.4%.³ Further work comparing rates across centres is needed to improve postoperative outcomes and help define best standards of practice.

The aim of this study was to audit the rate of SSIs requiring reoperation, which is currently not described in the literature. It is perhaps the most significant complication arising from SSIs as the need for further surgical intervention is an indication of the severity of the infection. Common risk factors for SSI were identified and these were tested against a control cohort. Using the endpoint of reoperation, we hoped to produce new figures against which other units could audit themselves as well as to understand the risk factors for this particular surgical complication. If significant risk factors for reoperation can be determined, this could facilitate early identification of high risk patients, guiding both surgical decision making and perioperative optimisation.

Methods

Using the hospital's electronic surgical database, all patients were identified who underwent neurosurgical intervention between 1 January 2010 and 31 December 2016 at King's College Hospital, a tertiary neurosurgical referral centre in London. The unit consists of four neurosurgical theatres (all with non-laminar airflow) located predominantly on one floor. Cranial, spinal and functional operations (including instrumented procedures) are performed in all theatres, and there is no particular preference in terms of the order in which they are carried out.

All patients undergoing surgery are given one dose of antibiotics at induction and those who undergo spinal instrumentation are given a further 24-hour course of antibiotics postoperatively. Patients receive a second dose of antibiotics intraoperatively if their operation lasts longer than six hours.

The keywords 'infect', 'washout', 'debridement', 'removal', 'exploration' and 'leak' were used with all their relative permutations to identify all patients requiring further surgery for management of SSIs. This information was confirmed by analysing operation records and clinical notes. Eligible cases were defined as those taken back to theatre for a suspected SSI. Additional criteria included clinical signs of infection plus evidence of infection at the surgical site (pus, wound dehiscence, erythema or cellulitis) and intraoperative findings of infective material with or without microbiological confirmation of microbial colonisation, as outlined by the Centers for Disease Control and Prevention (Appendix 1 – available online).

Cases were excluded from the study if they were admitted with primary cranial or spinal infections (eg abscess, empyema, discitis), or SSIs that developed following operations in other hospitals, and if there was absence of infective material on wound exploration as well as on subsequent microbiological culture. Patients with multiple operations performed at the same site for reasons other than SSI were also excluded to avoid duplicates in the data.

Using a validated random number generator, three age matched controls were selected randomly for each identified case. In order to improve statistical efficiency⁴ and address the anticipated wide spectrum of ages in our sample, frequency matching was performed based on three age groups (≤ 49 years, 50–69 years and ≥ 70 years). Control patients were defined as those who did not undergo further surgical intervention for a suspected SSI. Patients who died within seven days of the index surgery were excluded from the control group as this was thought to be an insufficient amount of time for these patients to have developed a SSI.⁵

Blinded data collectors compiled all patient data between 1 May 2016 and 30 May 2017 through the electronic patient record system. Demographic data (age and sex) were recorded, as well as known risk factors such as smoking and diabetes. Data were also collected for other risk factors such as length of operation preceding the infection, implantation of foreign material, perioperative steroid use, use of postoperative antibiotics and

postoperative wound leak. Other data recorded included the number of surgeons present during the operation, timing of surgery (normal working hours: 8.30am to 5pm) and whether the operation was performed in an emergency or an elective setting.

Statistical analysis

Multivariate binary logistic regression was used to analyse the risk of developing a SSI as a function of all potentially contributing factors identified. Factors were entered as covariates in the initial regression model via a forced entry method. The resulting model's goodness of fit was determined using the Hosmer–Lemeshow statistic. The proportion of variance in the occurrence of SSIs explained by the model was analysed using Nagelkerke's R^2 . Following this initial model, a reduced model was produced using covariates identified as significant predictors in the initial model (Wald statistic $\alpha < 0.1$). Multicollinearity of independent variables was assessed by examining tolerance and the variance inflation factor (VIF).

Results

A total of 16,513 patients underwent at least one neurosurgical procedure at our hospital during the 7-year study period. Of these, 224 had surgery for a suspected infection. Twenty-six of these cases were excluded from the study (21 patients had a primary infection and 5 had subsequent operations at other hospitals). Consequently, 198 infected cases were included in the study and 594 age matched

Table 1 Comparison of baseline characteristics

Characteristic	Cases (<i>n</i> =198)	Controls (<i>n</i> =594)	<i>p</i> -value
Median age in years	47.5 (IQR: 32–61)	47 (IQR: 32–59.5)	0.87*
Male sex	98 (49.5%)	294 (49.5%)	0.90**
Smoker	38 (20.7%)	139 (23.4%)	0.44**
Diabetes mellitus	26 (13.2%)	51 (8.6%)	0.06**
Emergency setting	73 (36.9%)	236 (39.7%)	0.48**

IQR = interquartile range
 *Non-parametric comparison of medians
 **Pearson's chi-squared test

controls were selected from the remaining cases (Fig 1). The seven-year SSI reoperation rate was 1.20% (198/16,515).

The baseline characteristics of the SSI and control groups are summarised in Table 1. Both cohorts were similar in terms of age, sex, smoking and diabetes status. The majority (84.8%) of the SSI cases were operated on during normal working hours. However, this did not take into account the acute nature of the required operations. The analysis was therefore expanded to compare the risk of reoperation for SSI in emergency and elective patients

Table 3 Reduced regression model using only statistically significant risk factors

Risk factor	Adjusted OR* (95% CI)	<i>p</i> -value
<i>Operative duration (ref <90 mins)</i>		
90–180 mins	1.61 (0.96–2.72)	0.07
>180 mins	1.85 (1.06–3.22)	0.029
Consultant-led	0.67 (0.43–1.03)	0.07
Instrumentation	2.74 (1.71–4.39)	0.000
Dexamethasone	3.55 (2.08–6.05)	0.000
Wound leak	27.41 (16.99–44.22)	0.000

CI = confidence interval; OR = odds ratio
 *Adjusted for all other risk factors by inclusion in multivariate logistic regression model

(Table 1). There was no statistically significant difference between these two groups.

The results of the initial multivariate logistic regression model are shown in Table 2. Type of surgery (cranial, spinal or functional), having more than one surgeon in theatre, drain use, lack of postoperative antibiotics and diabetes were not shown to be statistically significant risk factors, and so these were not included in the reduced model.

Table 3 summarises the results of the reduced regression model. The model was statistically significant

Table 2 Regression analysis for risk factors for surgical site infections

Risk factor	Crude OR (95% CI)	Adjusted OR* (95% CI)	<i>p</i> -value
<i>Procedure type (ref cranial)</i>			
Spinal	0.48 (0.33–0.71)	0.72 (0.39–1.32)	0.29
Functional	1.31 (0.78–2.20)	0.63 (0.18–2.25)	0.48
<i>Operative duration (ref <90 mins)</i>			
90–180 mins	1.12 (0.80–1.58)	2.63 (1.39–4.98)	0.003
>180 mins	2.31 (1.63–3.28)	2.36 (1.16–4.79)	0.018
<i>Number of surgeons (ref 1 surgeon)</i>			
2 surgeons	0.96 (0.69–1.33)	1.18 (0.60–2.31)	0.64
>2 surgeons	2.24 (1.53–3.30)	1.82 (0.79–4.19)	0.16
Consultant-led	0.66 (0.48–0.92)	0.52 (0.31–0.88)	0.014
Instrumentation	1.32 (0.95–1.85)	1.63 (0.92–2.89)	0.10
Drain use	2.59 (1.82–3.69)	1.34 (0.79–2.28)	0.27
Dexamethasone	3.29 (2.31–4.67)	3.03 (1.71–5.36)	0.000
Postoperative antibiotics	1.52 (1.06–2.18)	0.89 (0.49–1.63)	0.71
Wound leak	29.00 (18.55–45.27)	27.77 (16.36–47.15)	0.000
Diabetes	1.62 (0.98–2.68)	1.21 (0.56–2.62)	0.63

CI = confidence interval; OR = odds ratio

*Adjusted for all other risk factors by inclusion in multivariate logistic regression model

($\chi^2(7)=529.353$, $p<0.000$). It explained 50.4% of the variance in occurrence of SSI and correctly assigned 87% of cases. The largest contribution identified related to the patient having a wound or cerebrospinal fluid leak, which was associated with a 27.4-fold increase in the risk of developing a SSI that required reoperation. Other significant risk factors included operative duration, instrumentation and use of dexamethasone. The operation being led by a consultant surgeon was associated with reduced SSI reoperation risk although this was not significant at an alpha level of 0.05. No multicollinearity was identified between the variables (tolerance >0.1 and VIF <10).

Discussion

Wound/cerebrospinal fluid leak

Fluid leak from the operation site was by far the greatest risk factor for reoperation for SSI in our cohort with an odds ratio of over 27. Cao *et al* and Meng *et al* have both described cerebrospinal fluid leak as a risk factor for SSI^{6,7} but there has been little mention of persistent serosanguinous ooze in the literature. There is a limitation in our study of not being able to differentiate between the two since this is not often stated clearly in patient records. It is well recognised that the presence of a leak provides an environment in which bacteria can thrive and infection can spread. A leak may also be a sign that the wound itself is not well apposed and can therefore act as a warning for impending complications such as SSI.

Corticosteroids

Corticosteroids (particularly dexamethasone) are routinely used in neurosurgical units and are mentioned frequently in the literature as being a significant risk factor for SSI.⁷⁻⁹ Although they provide a wide array of benefits to patients, they are also associated with an immunosuppressant effect. Previous studies have shown that corticosteroids can impair wound healing by disrupting vital mechanisms at each stage of wound healing, from reducing macrophage infiltration at the inflammatory phase to reducing collagen formation at the remodelling phase.¹⁰ It is also important to note that long-term use of dexamethasone can cause impaired glucose control, which in itself is a well recognised risk factor for impaired wound healing.

Owing to the highly beneficial effects of corticosteroids, it is not feasible to suggest a change to the practice of prescribing these drugs. Nevertheless, it is important to be particularly vigilant for signs of SSI in this cohort of patients and to reduce steroid doses as soon as it is safe.

Instrumentation/drain use

Use of instrumentation doubled the risk of reoperation for SSI in our patients (odds ratio: 2.74, $p=0.000$). The placement of a foreign body during surgery raises concern since contamination can lead to deep seated infections. Other factors such as increased operative duration, use of allografts, blood transfusions and intraoperative imaging also contributed to increasing the risk of SSI in our cohort.¹¹ Such infections are often deeper seated; for this reason,

they can be difficult to treat and are likely to require further surgery to remove the offending instrumentation. Patients who have instrumentation fitted should therefore be followed up more closely, particularly those who may have other recognised risk factors (eg prolonged dexamethasone therapy), planned chemotherapy or radiotherapy, or other forms of immunocompromise.

A study performed by Ho *et al* in 2007 suggested that the use of surgical non-suction drains reduced the risk of SSI.¹² They hypothesised that draining the surgical bed of any postoperative haematomas or surgical material eliminated a medium in which bacteria could grow. However, this hypothesis has not yet been supported by a randomised controlled trial or other case studies and a review of the current literature yields mixed conclusions. Our department uses non-suction drains but the risk of reoperation for SSI in our cohort was still shown to be greater than that for cases without drain use (adjusted odds ratio: 1.34, $p=0.27$).

Operative duration

Operative duration is commonly cited in the literature as the most predictive risk factor for a SSI.^{6,13-15} Our model also showed that a longer operation significantly increased the risk of reoperation for subsequent SSIs. Any operation over 90 minutes more than doubled the risk. In neurosurgery, this could affect how patients are counselled, such as those considering intraoperative neuromonitoring with tumour resection. On the one hand, neuromonitoring allows us to be more aggressive in terms of debulking tumours located close to eloquent areas but this can also increase the length of the operation. While it was not possible to compare SSI rates for cases using neuromonitoring and cases without neuromonitoring, this study ultimately shows that increased operative duration may lead to infections, which carry greater morbidity and mortality.

Factors not found to be significant

The number of surgeons present, postoperative antibiotics, smoking and diabetes were not of statistical significance in our study. Conversely, diabetes remains a prevalent risk factor in many studies.^{7,16-18} Davies *et al* described implementing a care bundle to help prevent SSIs; this involved maintaining an intraoperative blood sugar level of $<11\text{mmol/l}$.¹⁹ Diabetic patients who have poorly controlled blood sugar levels are likely to be at greater risk of developing a SSI than those with well controlled blood sugar levels. While these data are difficult to capture in a retrospective analysis, it should be noted that simply using a record of a medical history of diabetes is a blunt instrument when attempting to stratify risk of infection and care should be taken to closely monitor the blood sugar levels of a patient, particularly if he or she is deemed at high risk of developing a SSI.

Prevention strategies

Understanding the burden of SSIs as well as significant risk factors can help us improve our practice with respect to preventing them. This study strengthens the knowledge that

various risk factors are associated with the development of SSIs, with few of these risk factors being modifiable. Smoking, diabetes, operative duration and perioperative dexamethasone have all been shown to inhibit satisfactory wound healing,^{1,5,9} which could in turn lead to wound leaks.

In addition, poor surgical technique may also be considered a risk factor as a more watertight closure may help prevent wound leaks. Obtaining such data can be difficult, and it may only lead to a reminder of the importance of good skin closure and close postoperative monitoring. This is similar with non-modifiable risk factors since knowing that a patient will have a longer operation, planned instrumentation and/or perioperative steroids can help us have more informed conversations with this individual. It also means we can increase our vigilance and perioperative optimisation of these patients.

Despite the many studies and guidelines that have been published, there is still a lack of clear protocols for best reducing SSIs. Nevertheless, a lot of recent work appears to point towards systems approaches involving the modification of the behaviour of all stakeholders (from surgeon to healthcare assistant) as being the most important consideration.²⁰ As our study was retrospective, it was not possible to determine other related factors such as hair shaving or the nature of the surgical dressings used post-operatively for each patient in this study. However, current national guidance in England on SSI prevention only recommends not routinely removing hair, prescribing prophylactic antibiotics for instrumentation/clean-contaminated/contaminated procedures, good skin preparation and covering incisions with appropriate dressings.⁵ It is with the appropriate use of these simple measures that we can perhaps make the most difference.²¹

Published literature reviews of preoperative skin preparation also yield mixed results. In 2016 Davies and Patel demonstrated an 88% reduction in the risk of SSI when using a combined preparation of chlorhexidine (CGH) and povidone-iodine (PVI) rather than either agent by itself.²² They did not identify a difference in SSI risk between the two agents if used separately.

This finding has been supported by a randomised controlled trial performed by Patrick *et al* in 2017, looking at whether a combination of CGH and PVI in spinal surgery reduced the risk of skin contamination compared with CHG applied twice.²³ Skin culture counts were significantly lower in patients treated with a combination skin preparation than in those treated with CHG on its own. Conversely, two separate meta-analyses in 2017 (by Privitera *et al* and Zhang *et al*) comparing CHG and PVI found the former to be the favourable agent as it was associated with fewer positive skin cultures and lower SSI rates.^{24,25}

Despite the abundance of literature on this topic, there is still no approved protocol regarding optimal skin preparation techniques and so different units will prepare the skin differently, with cost implications also being a factor. There is even discordance as to whether lengthy skin preparation has the greatest effect on skin microbial counts as

Cronquist *et al* did not identify a reduction in skin colony forming unit counts following skin preparation.⁸ This might lead us to rethink lengthy skin preparation, especially given the known risk of increasing the operative duration.

Our unit adheres to the policy of all elective surgery patients being provided with an antimicrobial wash prior to their planned admission. A further wash is supplied on the day of admission, to be used on the morning of their operation. An anonymous survey handed out to patients on the elective admission ward showed a 100% compliance rate with this protocol.

Furthermore, there is evidence that strategies adopted in one country may not work in another. A large study conducted across the US, Denmark and Japan demonstrated that the importance of different risk factors varies between countries, and so risk stratification models developed in one country may not be directly applicable to other countries.¹⁶ Meng *et al* performed a review of the literature and identified 25 case controlled studies addressing risk factors for SSI.⁷ Although they managed to find several common risk factors, they expressed caution with interpreting the findings since there was a strong degree of heterogeneity between the results of the different studies reviewed.

What this perhaps directs us towards is enhanced surveillance of our own practice through auditing as well as creating a national database that allows all centres to collect information on SSI patients being readmitted to neurosurgical centres for reoperations or conservative management. This is particularly important for those identified as being at high risk of SSI owing to recognised risk factors. It would then be possible to better understand the principal risk factors as well as the burden on the NHS.

Study limitations

This study only evaluated the rate of SSIs requiring further surgical intervention, not the proportion of patients with SSIs overall. Patients who developed postoperative meningitis or other medically managed SSIs were not considered as these cases are not routinely recorded on a database, making it more difficult to find such individuals retrospectively. It is also important to note that not all patients with SSIs will present back to their surgical units; some may be treated conservatively in the community through their local general practitioner or at their local hospital. However, one way to allow better recognition would be to create a national database to document all SSIs, whether treated in the community (ie with antibiotic therapy) or in a hospital setting.

There are also clear limitations with capturing accurate data for patients undergoing surgery. For example, patients may be reluctant to disclose their smoking status. As a result, the data from history taking may not be completely reliable. It has also been hypothesised that nursing staff turnover in the operating theatre is more important than the number of surgeons and this (together with other operating theatre practice) is not always recorded accurately.²³

Conclusions

Our retrospective analysis of 16,513 patients operated on over a 7-year period showed that 1.20% of patients required at least one further operation to treat a SSI. Wound leak, dexamethasone use, instrumentation and increased operative duration were the most significant risk factors for SSI. Together with other recognised risk factors (such as smoking, diabetes, high body mass index and immunosuppressant therapy), the risk factors identified in our study can significantly increase the risk of developing a SSI. A detailed comprehension of the risk factors that can predict readmission for SSI is of obvious clinical significance. A better understanding of the scale of this issue is also important in terms of auditing practice.

A departmental surveillance system like that currently being implemented by Public Health England would allow early identification of all high risk patients. Various risk factors are associated with the development of SSIs and by recognising high risk patients in the early stages of their care, these individuals can be counselled appropriately to enable them to have the best healing outcome following surgery, which can reduce the economic burden on the NHS.

Acknowledgement

The material in this paper was presented at the Autumn Meeting of the Society of British Neurological Surgeons held in Liverpool, September 2017.

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