Infection

Risk factors for surgical site infections in neurosurgery patients with antibiotic prophylaxis

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Received 1 December 2003; accepted 12 April 2004

Abstract

Background: This prospective study aimed to determine the spectrum and the main risk factors of surgical site infection (SSI) after neurosurgical procedures in our clinic.

Methods: Consecutive patients undergoing neurosurgery between November 1, 2001, and November 1, 2002, were recruited for the study. All patients were followed for a minimum of 2 weeks postoperatively and all SSIs were recorded. The complete medical records of each case were reviewed, and data on 14 possible risk factors were extracted. Statistical analyses were performed to identify the risk factors for SSIs.

Results: A total of 31 postoperative SSIs were identified among 503 cases included in the study, with a resulting overall infection rate of 6.2%. The risk of SSI was increased by age (odds ratio [OR], 1.1; 95% confidence interval [CI], 1.0-1.1; \( P = .039 \)), operation type such as “shunt operations” (OR, 670.4; 95% CI, 2.6-17123.1; \( P = .021 \)), presence of foreign body (OR, 141.0; 95% CI, 2.5-7925.9; \( P = .016 \)), presence of diabetes mellitus (OR, 24.3; 95% CI, 2.1-284.9; \( P = .011 \)), and intracranial pressure monitoring (OR, 4878.9; 95% CI, 23.8-1001 229; \( P = .002 \)). The predominantly isolated microorganisms in patients with SSIs were Staphylococcus aureus (22 [71.0%]), Acinetobacter baumanii (5 [16.1%]), and Staphylococcus epidermidis (4 [12.9%]).

Conclusions: SSIs remain an important problem in neurosurgery. Identification of the risk factors for SSI will help physicians to improve patient care and may decrease mortality, morbidity, and health care costs of neurosurgery patients.

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Keywords: Infection; Neurosurgery; Prophylaxis; Risk factor; Wound infection

1. Introduction

Surgical site infections (SSIs) are the most common and serious complications among surgically treated patients, resulting in increased rates of morbidity and mortality, length of stay in hospital, and cost [21,24]. Despite the number of publications in which risk factors for SSI in patients having undergone neurosurgical operation have been detailed, the nature and magnitude of these risk factors are not clear.

The average SSI rate without antibiotics ranges between 5% and 11% in cerebrospinal fluid (CSF) shunts, between 1% and 5% in craniotomies and spinal surgery in clean and clean-contaminated patients, and between 11% and 38% in CSF fistulas [3,9,12,13]. Because of the potentially devastating consequences of infectious complications, considerable efforts should be made for reduction of the infection rates in neurosurgery.
This present study aimed to determine the spectrum and the main risk factors of SSI after neurosurgical procedures in our clinic.

2. Material and methods

This study was carried out between November 1, 2001, and November 1, 2002, at the Department of Neurosurgery, School of Medicine, Çukurova University. This study was approved by the Ethics Committee of the School of Medicine, Çukurova University. All patients undergoing elective neurosurgical operations during the study period were eligible for inclusion, with the exception of the following: those who did not give their consent for inclusion in the study; those who were allergic to cephalosporins; and those with an infectious disease such as brain abscess, subdural or epidural empyema, osteitis, or scalp infection.

2.1. Study procedure

Surgically treated neurosurgery patients were recruited in this study. All patients received cephalosporin group antibiotics (ie, cefoperazone) for prophylaxis. The anesthesiologist administered the antibiotics according to the prescribing information. The infusion was started after the induction of anesthesia, so that the peak blood levels of antibiotics were reached during the operation. Further doses were given for every 3 hours of the operation. If patients had been previously operated on in the same anatomic localization, each received 2 g of antimicrobial agent with the same protocol. Emergency cases were not included because of the difficulty of administering the antibiotics when time was at a premium and the usual anesthetic and nursing staff, familiar with the regimen of administration, were not present. In case of a second surgery in a previously untouched localization or a subsequent neurosurgical operation 6 weeks later, it was considered a new case.

All patients underwent the same protocol in preparation for surgery. The hair in the operative field was shaved. The skin was prepared with povidone-iodine followed by alcoholic chlorhexidine. The surgical field was draped with a sterile towel and sealed off with adhesive transparent plastic. For wound closure, the subcutaneous tissue was approximated with polyglactin and the skin with polyethylene.

Between November 1, 2001, and November 1, 2002, 630 neurosurgical operations were performed at the Department of Neurosurgery, Çukurova University Hospital. Of these, 75 (11.9%) did not fulfill the criteria for inclusion in the study, because 1 (0.2%) was allergic to cephalosporins, 17 (2.7%) had an infectious disease requiring antibiotic treatment, and 50 (7.9%) were emergency cases. A further 27 (4.3%) were excluded because of the following reasons: death shortly after the operation (15 cases) and absence of informed consent for participation in the study (12 cases) obtained from the patient or his/her companion in case of unconsciousness. Twenty-five patients (4.0%) underwent a second operation within 6 weeks of randomization; the same prophylactic antibiotics were used in these operations as in the original operation as specified by the study protocol, and the data from the second operations were not repeated in the study analyses.

The complete medical records of each of the remaining 503 (79.8%) cases were reviewed, and data on possible risk factors were extracted. The data collected included information such as demographic data, diagnosis, presence of diabetes mellitus, use of glucocorticoids, level of consciousness and mobility, nature and duration of operation, use of a postoperative drain, use of external lumbar drainage, permanence of intracranial pressure (ICP) monitoring instrument, placement of a foreign body, entry into paranasal sinuses, presence of CSF leak, and length of postoperative hospital stay in the neurosurgery intensive care unit (NICU). Paranasal sinus entry was defined as a recognized violation of any of the paranasal sinuses or mastoid air cells at the time of surgery. Placement of a foreign body was recorded when metal implants, shunt devices, bone implants, aneurysm clips, and wire sutures, but not bullets or other foreign bodies, were intentionally left in the surgical area. Postoperative drain placement included a variety of closed and open drainage systems left in place from several hours to several days postoperatively. Postoperative CSF leak was recorded when such drainage was diagnosed postoperatively on the basis of otorrhea, rhinorrhea, or leakage from the surgical wound. The duration of operation was recorded as 3 hours and longer, or shorter than 3 hours. The duration of hospitalization in the NICU was recorded as less than 3 days, 3 to 10 days, and more than 10 days. Presence of diabetes mellitus was defined on the basis of clinical and laboratory data. The use of glucocorticoids, ICP monitoring, and external lumbar drainage was also recorded.

2.2. Definition of SSI

If any infection occurred or was suspected, except nonpurulent SSI cases, the causative pathogen was identified and appropriate antibiotics were given. Two physicians assessed patients for the occurrence of infectious complications. All patients were followed for a minimum of 2 weeks postoperatively and SSI was recorded. Surgical site infections were accepted as superficial incisional, deep incisional (soft tissue), or organ/space infections (intracranial, osteomyelitis, disc space, spinal abscess, meningitis, or ventriculitis). Hyperemia and local warming at surgical site was also accepted as a criterion for superficial incisional SSI.

The main outcome of the study was whether a patient developed an SSI. The \( \chi^2 \) test or the Fisher exact test was used to determine the significant differences between categorical variables, and \( t \) test was used for one
continuous variable. The variables that were found to be significant \( (P \leq 0.05) \) in the univariate analysis were taken into logistic regression.

### 3. Results

The study included a total of 503 patients undergoing neurosurgical operations, grouped as 197 (39.2\%) craniotomies, 154 (30.6\%) spinal operations, 78 (15.5\%) burr hole operations, and 74 (14.7\%) shunt operations.

A total of 31 postoperative SSIs were identified among 503 cases included in the study, with a resulting overall infection rate of 6.2\%.

When the relationship was studied in the regression model, statistically significant relation was found among variables including age, operation type such as “shunt surgeries,” placement of foreign bodies, diabetes mellitus, and ICP monitoring. The final logistic regression model with the significant and nonsignificant risk factors for SSI is presented in Table 1, and statistically significant influencing factors were emphasized as summarized below (Fig. 1).

| Table 1 | The final logistic regression model of influencing factors for SSIs |
| :---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Age, mean ± SD (y) | (+) SSI, n (%) | (-) SSI, n (%) | Total, n (%) | OR | 95% CI | \( P \) value |
| 35.7 ± 25.3 | 32.6 ± 23.4 | | 1.1 | 1.0-1.1 | .039* |
| Gender | | | | | | |
| Male | 17 (6.7) | 238 (93.3) | 255 (50.7) | Reference |
| Female | 14 (5.6) | 234 (94.4) | 248 (49.3) | 3.3 | 0.4-27.9 | .265 |
| Type of surgery | | | | | | |
| Burr hole operation | 2 (2.6) | 76 (97.4) | 78 (15.5) | Reference |
| Spinal operation | 6 (3.9) | 148 (96.1) | 154 (30.6) | 15.8 | 0.1-2288.9 | .276 |
| Craniotomy operation | 15 (7.6) | 182 (92.4) | 197 (39.2) | 0.0 | 0.0-4 \times 10^{33} | .806 |
| Shunt operation | 8 (10.8) | 66 (89.2) | 74 (14.7) | 670.4 | 2.6-171 \times 10^{3} | .021* |
| Use of postoperative drain | | | | | | |
| Not used | 8 (2.7) | 293 (97.3) | 301 (59.8) | Reference |
| Used | 23 (11.4) | 179 (88.6) | 202 (40.2) | 14.3 | 0.5-456.0 | .131 |
| Entry of paranasal sinus | | | | | | |
| Not present | 23 (4.9) | 444 (95.1) | 467 (92.8) | Reference |
| Present | 8 (22.2) | 28 (77.8) | 36 (7.2) | 0.3 | 0.0-113.5 | .684 |
| CSF leak | | | | | | |
| Not present | 13 (3.2) | 398 (96.8) | 411 (81.7) | Reference |
| Present | 18 (19.6) | 74 (80.4) | 92 (18.3) | 8.5 | 0.7-105.9 | .097 |
| Duration of operation (h) | | | | | | |
| <3 | 12 (3.4) | 338 (96.6) | 350 (69.6) | Reference |
| ≥3 | 19 (12.4) | 134 (87.6) | 153 (30.4) | 0.1 | 0.0-5.6 | .285 |
| Duration of postoperative stay in NICU (d) | | | | | | |
| 0 | 7 (3.2) | 212 (96.8) | 219 (43.5) | Reference |
| 1-2 | 7 (4.9) | 135 (95.1) | 142 (28.2) | 3.1 | 0.1-71.7 | .475 |
| 3-10 | 9 (10.7) | 75 (89.3) | 84 (16.8) | 0.1 | 0.0-16.7 | .428 |
| >10 | 8 (13.8) | 50 (86.2) | 58 (11.5) | 3.4 | 0.0-290.1 | .595 |
| Placement of a foreign body | | | | | | |
| Not present | 8 (2.4) | 320 (97.6) | 328 (65.2) | Reference |
| Present | 23 (13.1) | 152 (86.9) | 175 (34.8) | 141.0 | 2.5-7925.9 | .016* |
| Diabetes mellitus | | | | | | |
| Not present | 16 (3.9) | 392 (96.1) | 408 (81.1) | Reference |
| Present | 15 (15.8) | 80 (84.2) | 95 (18.9) | 24.3 | 2.1-284.9 | .011* |
| Status of consciousness | | | | | | |
| Conscious and mobile | 15 (4.2) | 346 (95.8) | 361 (71.8) | Reference |
| Conscious and nonmobile | 4 (6.8) | 55 (93.2) | 59 (11.7) | 0.0 | 0.0-5 \times 10^{15} | .837 |
| Unconscious and nonmobile | 12 (14.5) | 71 (85.5) | 83 (16.5) | 2.1 | 0.1-78.8 | .681 |
| Use of glucocorticoids | | | | | | |
| Not used | 6 (2.4) | 248 (97.6) | 254 (50.5) | Reference |
| Used | 25 (10.0) | 224 (90.0) | 249 (49.5) | 4.4 | 0.4-49.6 | .229 |
| Use of ICP monitoring | | | | | | |
| Not used | 20 (4.2) | 452 (95.8) | 472 (93.8) | Reference |
| Used | 11 (35.5) | 20 (64.5) | 31 (6.2) | 4878.9 | 23.8-1.0 \times 10^{6} | .002* |
| Use of external lumbar drainage | | | | | | |
| Not used | 12 (2.5) | 466 (97.5) | 478 (95.0) | Reference |
| Used | 19 (76.0) | 6 (24.0) | 25 (5.0) | 8 \times 10^{11} | 0.0-1.8 \times 10^{73} | .704 |

* Line percentage.  
\(^{b}\) Column percentage.  
* \( P < .05 \).
Staphylococcus aureus with 22 (71.0%) cases, Acinetobacter baumannii with 5 (16.1%) cases, and Staphylococcus epidermidis with 4 (12.9%) cases were frequently isolated from patients with SSIs.

3.1. Risk factors for SSIs

Five risk factors (age, operation type such as shunt surgeries, placement of foreign bodies, diabetes mellitus, and ICP monitoring) showed significant association with postoperative SSIs. The age increased the risk for SSI by approximately 1.1-fold (95% confidence interval [CI], 1.0-1.1), whereas shunt operations approximately 670.4-fold (95% CI, 2.6-171123.1), presence of foreign body approximately 141.0-fold (95% CI, 2.5-7925.9), presence of diabetes mellitus approximately 24.3-fold (95% CI, 2.1-284.9), and ICP monitoring approximately 4878.9-fold (95% CI, 23.8-1001229). The other factors (gender, use of postoperative drain, level of consciousness and mobility, entry of paranasal sinus, presence of CSF leak, duration of operation, length of postoperative hospital stay in the NICU, use of glucocorticoids, and use of external lumbar drainage) found to be significant risk factors for SSI in univariate analysis were found not to increase the SSI risk in the logistic regression model ($P > .05$).

The mortality rate attributable to SSIs was 6.4%, with 2 of 31 cases with SSIs.

4. Discussion

Neurosurgeons have traditionally reported postoperative infection rates substantially lower than those reported by their general surgeon colleagues. However, the introduction of longer microsurgical procedures and the increasing use of implanted foreign materials such as shunts, clips, implant material for spinal stabilization, and cranioplasty plates have increased the theoretical risk of perioperative infection.

Although, in terms of importance, postoperative wound infection is well down the list of causes of mortality and morbidity in neurosurgical practice, the occurrence of this presumably preventable complication is a recurring frustration.

The range of infection in clean neurosurgical operations in randomized controlled trials [4,6,8,9,12,15,18,20,33,41] is 4.0% to 12.0% without prophylactic antibiotics and 0.3% to 3.0% with prophylactic antibiotics. Currently, an incidence of infectious complications less than 5% is considered acceptable [15,19]. The total SSI rate of 6.2% in our series was similar, being slightly higher than the acceptable range.

The potentially devastating effects of postoperative infection in the central nervous system have inspired continuing interest in a better understanding of the factors leading to postoperative SSI. Potential risk factors for infection and importance of each factor have been identified [6,23,30,32,33,43]. We analyzed the experience with postoperative SSIs and attempted to estimate the magnitude of risk associated with several characteristics in these patients and their operations.

A variety of risk factors for SSI in neurosurgery have been reported. The first studies of Balch [2] and Wright [46] identified certain factors that they had believed to be associated with an increased risk of postoperative wound infection. Tenney et al [43] found an overall deep wound infection rate of 2.6% and a superficial infection rate of 2.9%, and the type of procedure, duration of the operation, and nature of the preparation for surgery appeared to influence the incidence of wound infection. Subsequent studies have confirmed that some of these risk factors appear to be important [22,30,32,33,43]. Mollman and Haines [30] reported that the presence of a CSF leak and a concurrent non–central nervous system infection increased the estimated relative risk of infection to 13:1 and 6:1, and use of perioperative antibiotics decreased the risk of infection to approximately 20% of the control level. Mollman and Haines [30] also reported that no association was found between operation duration and infection risk.

Korinek [23] reported that the presence of a CSF leak and subsequent operation are independent risk factors, and emergency surgery, clean-contaminated and dirty surgery, an operative time longer than 4 hours, and recent neurosurgery are independent predictive risk factors for SSIs. Postoperative incontinence, posterior approach, surgery for tumor resection, dural tear, use of glue to cement the dural patch, and morbid obesity were reported as risk factors for SSI after spinal surgery [28]. Other factors such as diabetes mellitus [42,44] also contribute to the development of SSIs. Other retrospective studies report that obesity, surgical reexploration, steroid administration, and increased hospital stay for patients with infections have no relation to SSIs [12].

Our data showed that age, operation type such as shunt surgeries, placement of foreign bodies, diabetes mellitus, and ICP monitoring were substantial risk factors for
postoperative SSIs. Cronquist et al [11] reported the relation of age with SSIs, with younger people at higher risk. Other studies have found that older age predicts increased SSI risk [26,27], as proven by our study, or has no effect on SSI [17,31]. Our study did not present any relation between SSIs and gender.

Intracranial pressure monitoring, duration of ICP monitoring longer than 5 days, CSF leak, and serial ICP monitoring were found as risk factors for CSF infection [1,3,5,45]. However, Winfield et al [45] reported that no relation was found between the duration of ICP monitoring and the daily infection rate through the period of maximal 2 weeks of monitoring. Our series supported the risk as a result of ICP monitoring, but external lumbar drainage was not found as a risk factor for SSI.

Surgical sites of infection probably arise from contamination during the operation. The patient should therefore be loaded with antimicrobial drugs before the skin incision and the infusion should be continued until the wound closure. In 1976, Savitz and Malis [40] reported that all infected patients had undergone microneurosurgical procedures lasting more than 6 hours. Our study similarly indicated that the duration of operation did not affect the SSI rate, suggesting the positive effect of an additional dose of antibiotic preferred in operations lasting more than 3 hours.

The use of antibiotic prophylaxis in neurosurgery is controversial, although many centers, including ours, prefer to administer antibiotics to all patients. In randomized controlled trials [3,5,7-10,13-16,24,31,37-39], antibiotic prophylaxis has been shown to decrease the rate of SSIs in clean neurosurgical operations. In our study, shunt surgery considerably increased the risk for SSI, a situation consistent with the results of other studies. Incidence of shunt infections ranges from 2% to 33%, with an average of 10% [25,29,36]. Identification of risk factors for shunt infection may improve current methods to prevent shunt infections. Premature birth, previous shunt infection, intraoperative use of the neuroendoscope, presence of a postoperative CSF leak, dermatologic disorders, and number of times the shunt system was inadvertently exposed to breached surgical gloves were reported as independent risk factors for shunt infection [25,29,34,36]. Haines and Walters [19] reported that antibiotic prophylaxis had reduced the risk of shunt infection, but that was limited, as in our series. Other measures suggested to prevent infections include meticulous surgical technique, minimal manual contact with shunt system in the operation, changing gloves before handling the shunt, covering the wound edges with antiseptic-soaked packs during surgery, impregnating the catheters with antibiotics, and avoiding any postoperative CSF leak [25,29,34].

Bacteria found in neurosurgical SSIs, as reported [3,5-8,12,13,22,23,39], are mainly gram-positive cocci, particularly S. aureus and S. epidermidis as in our series. A. baumanni with 5 (16.1%) cases was observed as the second most frequent organism in our study.

5. Conclusions

Surgical sites of infection remain as an important problem in neurosurgery. Identiﬁcation of the risk factors for SSI will help physicians to improve patient care and may decrease mortality, morbidity, and health care costs of neurosurgery patients.

References


### Commentaries

Most neurosurgical infections are caused by resident, cutaneous bacteria on the scalp and back. These include coagulase-negative and coagulase-positive *Staphylococcus*, *Propionibacterium acnes*, and gram-negative bacilli. Although some studies have shown that the density of bacteria (bacterial counts) at the operative site correlates with postinfectious outcomes, others were unable to detect an association between postoperative bacterial skin counts and SSI. *Staphylococcus capitis* and *P acnes* are 2 organisms usually found on the face and scalp, areas with relatively high sebum production, whereas other staphylococci are ordinarily found in drier areas of the back.

Reported rates of infection following neurosurgery vary from 0% to 15% in clean cases. With the use of prophylactic antimicrobials, a significant reduction in the risk of SSI results. In the current study, the risk was 6.2% and was primarily in older patients, in those with diabetes, and where prophylactic prophylaxis is used, all factors that serve to reduce immunocompetence in the host. Obesity and corticosteroids have similarly been implicated by others. Although cephalosporins are active against most of the organisms mentioned above, the development of resistance among the *Staphylococci* and gram-negative bacilli may require different antimicrobials in the future.

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Bacterial colonization after neurosurgery is a fearful condition accompanied by high mortality, and prospective studies aimed to detect risk factors are scarce. As in all serious complications, preventive measures in subjects at increased risk will improve surgical effectiveness and greatly reduce the associated costs. The study by Erman et al shows, on the side of patient, 2 main risk factors for infection: increased age and diabetes, and on the side of surgery, 2 more risk factors, shunting for hydrocephalus and presence of artifacts for monitoring ICP. With this scenario, the neurosurgeon can be taken to diminish the rate of infections. The integral approach of medical and surgical teams for elderly subjects should be particularly well integrated so that the patient enters the surgical theater in the best possible condition to deal with the surgical trauma; similarly, in patients with diabetes, metabolic and immunologic variables should be carefully optimized. It has long been known that the possibility of bacterial colonization of any external instrument in contact with the nervous tissue increases in
direct relation with the time of its permanence; in the light of this study, these instruments should remain in contact with the nervous tissue in the least possible time, and this precaution would be even more important in patients with diabetes and in elderly patients. The subject of infection in patients with hydrocephalus treated with shunts has long been debated. Bacterial colonization of shunting devices is frequent, the valvular mechanisms are prone to bacterial colonization, and the long periods of fluid stasis favor ascending infections. The study of Erman et al also shows that in agreement with many other reports, staphylococci are conspicuous agents in infections secondary to neurosurgical procedures.

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Private Spending. In nations with socialized medicine that permit a “two-tier” system, the portion of the medical dollar spent on private insurance and medical care is: Denmark, 18%; Japan, 19%; Germany, 22%; France, 24%; Italy, 24%; Australia, 32%; Netherlands, 36%; Switzerland, 42%; United States, 56% (The Economist 7/17/04).

—Association of American Physicians and Surgeons (AAPS)
Vol 60, No 11, November 2004