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Reduction of Postoperative Spinal Infections Based on an Etiologic Protocol

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Acute postoperative spinal infections are serious complications. We saw a sudden increase in the infection rate in our unit during a 6-month period. This led us to construct an assessment protocol combining risk factors into a mnemonic we named the "Nine Ps Protocol" (patient-related factors, personnel, place, preoperative length of stay, procedure, prosthetics, prophylaxis, packed red blood cells, and pus cultures). We reviewed 102 consecutive patients having spine surgery in three sequential 6 month periods: Group A included 34 patients before the outbreak of infection and Group B included 26 patients during the outbreak of infection. We prospectively applied the protocol in 26 patients (Group C) after the outbreak. After the implementation of the protocol the infection rate dropped from 16.7% (Group B) to 3.6% (Group C). Increased risk factors for postoperative infection included advanced age, posterior instrumented fusion, high allogenic blood transfusion rates, and suboptimal sheet and dressing changing conditions. We propose the Nine Ps Protocol as a useful clinical tool for the etiologic assessment and prevention of spinal infections.

Level of Evidence: Prognostic study, Level II (Lesser quality prospective study [eg, patients enrolled at different points in their disease or < 80% followup]). Please see Guidelines for Authors for a complete description of levels of evidence.

Infection is one of the most common causes of increased morbidity in the acute phase of spinal surgery.[4,21] Despite advances in sterility and perioperative chemoprophylaxis, postoperative deep wound infections remain one of the most unfortunate and potentially devastating complications. The presence of pus at the operative site and a microbiologic culture positive for one or more organisms are reliable indicators of a wound infection.[1,16] We consider acute postoperative spinal infections as those identified within the first 3 weeks after spinal surgery.[30] They may be deep or superficial, with those occurring beneath the lumbodorsal fascia considered deep.[2,3] The reported incidence of acute postoperative spinal infections ranges from less than 1% to 13%.[1,4,27,31] The routine use of prophylactic antibiotics perioperatively has led to a reduction of postoperative spinal infections to less than 6%.[33] The type of the procedure also influences the infection rate. Simple lumbar discectomies without fusion carry a relatively small risk of 1% to 2%.[3–5,14,17,21,22] In microdiscectomy, procedures the rate increases to 5%.[8] In instrumented posterior lumbar fusions, the incidence ranges between 2% and 6%.[3–5,9,11,14,17,20,22] Most authors agree that rates higher than 10% are considered unacceptable for any type of procedure.

An acute increase in the rate of postoperative spinal infections is disturbing for patients, surgeons, and all personnel involved in the patient's care.[31] The safety of elective and trauma operations becomes unpredictable and mean hospital stays and medical and social costs escalate.[6,17] Ultimately, if not promptly addressed, such increases may jeopardize the spinal unit itself. Although several authors have emphasized the importance of postoperative spinal infections, there is a lack of a relevant clinical assessment tool.

A specific protocol for the reduction of postoperative spinal infections should include all relevant predisposing risk factors. According to such a protocol, any condition identified as a contributing factor could be addressed when it is recognized. Simplicity and accuracy in the protocol's construction can contribute to its easy application and acceptance. We developed such a clinical protocol.

We proposed the prospective use of this protocol would reduce a high infection rate.

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MATERIALS AND METHODS

A new clinical protocol was developed in our unit after an outbreak of postoperative spinal infections. The protocol was applied prospectively over a 6-month period in a group of consecutive patients who had major spinal operations. Its efficacy in reducing the rate of infections in a clinical setting was validated. The same protocol was applied retrospectively in consecutive patients during the previous 1-year period. These retrospectively identified patients were subdivided into two subgroups constituting all patients in two 6-month periods, before and during the outbreak of infections.

We reviewed 102 consecutive patients who had spinal surgery from August 2002 to February 2004. Another 31 patients during the same period had core spinal biopsies under local anesthesia and were excluded from the study because of the diagnostic nature of these procedures, which have very low infection risk. The studied patients were divided into three groups (Table 1). Each group represents a 6-month period: before, during, and after the outbreak of acute postoperative spinal infections. Group A (August 2002 through January 2003) had 34 patients. These patients represent the period before the increase in the infection rate and were studied retrospectively. Group B (February 2003 through July 2003) had 42 patients. Seven of these patients developed an acute postoperative spinal infection (16.7%). Groups A and B were used as controls and were compared with patients in Group C, who were studied prospectively. Group C (August 2003 through February 2004) had 26 patients. All groups included patients of various ages with miscellaneous underlying pathologies (Table 1). All operations were performed by the same experienced spinal surgeon (AC), who had a low infection rate in more than 3500 spinal procedures during the past 20 years. There were nine assistants for Group A, nine for Group B, and eight for Group C.

An independent observer (PS) was allowed full access to the patients' files and each patient was studied separately. Information was retrieved from patients' notes, drug charts, anesthetists' assessments and intraoperative charts, blood bank data, and microbiology culture results. Infection rates during the same study period among other orthopaedic procedures from the same department and spinal procedures done in the Department of Neurosurgery also were assessed. This latter department is situated in the same floor and operations are done in the same, shared operating rooms and assisted by the same nursing staff.

The development of the protocol was based on previous studies and combined all known etiologic factors responsible for the occurrence of a postoperative spinal infection. All identified predisposing factors that were amenable to risk-reducing interventions were addressed on recognition. The risk factors were identified in a mnemonic device we named the "Nine Ps Protocol." The protocol consisted of (1) patient-related factors, (advanced age, malnutrition, smoking, alcohol/drug abuse, obesity, diabetes mellitus, rheumatoid arthritis, immunosuppression and/or steroid therapy, surgery for tumor resection, infection in remote sites, bladder and/or bowel incontinence); (2) personnel involved in the infected cases (surgeon, assistants, scrub and/or circulating nurse, nursing staff on the wards, residents); (3) place (wards, operating theatre, ICU); (4) preoperative length of stay; (5) procedure (type of procedure, revision and/or staged surgery, duration of procedure, surgical technique); (6) prosthetics (type of material used, total number of different material inserted in the same patient, sterility and/or storage conditions, new material introduced before the onset of infections); (7) prophylaxis (type of antibiotics, duration of administration, omitted doses); (8) packed red blood cells (number of units transfused per patient, use of allogeneic blood or autologous transfusion); and (9) pus culture results (responsible microorganisms, Gram stain, virulence, possible origin [skin, bowel, urinary tract, hospital flora, ICU flora]).

For transfusion in particular, only the units transfused before the onset of a postoperative spinal infection were considered. Moreover, only the allogenic packed red blood cell units were recorded as a possible risk factor for a postoperative spinal infection. Therefore, preoperative autologous donated units and those collected intraoperatively with a blood saver were not included.

Continuous variables were summarized using medians with interquartile ranges (IQRs), because data were not normally distributed. Differences among groups with respect to continuous variables were tested using the Kruskall–Wallis test and the Mann–Whitney U test. Associations between the groups and other qualitative factors were analyzed using the chi square test

TABLE 1. Diagnosis

Diagnosis	Group A	Group B	Group C	Sum
Scoliosis	2	7	0	9
Disc herniation	14	8	9	31
Spinal stenosis	6	6	6	18
Spondylolisthesis	2	3	1	6
Tumor	3	5	2	10
Fracture	2	9	6	17
Removal of metalwork	4	2	2	8
Various	1	2	0	3
SUM	34	42	26	102
Median age in years (IQR)	44.0 (27.5–64.0)	51.0 (31.5–61.3)	53.5 (35.8–68.5)	NA

IQR = Interquartile range; NA = Not applicable

TABLE 2. Factor Comparison

Patient Characteristics	Group A n = 34	Group B n = 42	Group C n = 26	p Value*
Median age in years (IQR)	44.0 (27.5–64.0)	51.0 (31.5–61.3)	53.5 (35.8–68.5)	0.394†
Number of men (%)	16 (47.1)	17 (40.5)	14 (53.8)	0.556‡
Number of diagnoses (%)				0.313§
Scoliosis	2 (5.9)	7 (16.7)	0 (0)	
Herniated disc	14 (41.2)	8 (19.0)	9 (34.6)	
Spinal stenosis	6 (17.6)	6 (14.3)	6 (23.1)	
Removal of metalwork	4 (11.8)	2 (4.8)	2 (7.7)	
Tumor	3 (8.8)	5 (11.9)	2 (7.7)	
Fracture	2 (5.9)	9 (21.4)	6 (23.1)	
Spondylolisthesis	2 (5.9)	3 (7.1)	1 (3.8)	
Various	1 (2.9)	2 (4.8)	0 (0)	
Median preoperative length of stay in days (IQR)	3 (2–6)	2 (0–5)	4 (1–10)	0.075†
Number of fusion procedures (%)	16 (47.1)	33 (78.6)	16 (61.5)	0.034‡
Median time of procedure in hours (IQR)	2.0 (1.2–3.6)	2.3 (1.5–3.6)	2.0 (1.5–3.8)	0.569†
Median number of patient-related risk factors (IQR)	1 (1–2)	1 (0–2)	1 (1–2)	0.214†
Number of infections (%)	0 (0)	7 (16.7)	1 (3.8)	0.032§

*Bonferroni-adjusted p-values
†Kruskall-Wallis test
‡Chi square test
§Fisher's exact test
IQR = Interquartile range

or Fisher's exact test whenever the expected count was less than 5. Bonferroni correction was used to adjust for multiple comparisons because the same data were compared twice (once among groups and then between infected and noninfected groups). All statistical tests were two tailed and significance was set at 0.05. Statistical analyses were conducted in SPSS 12.0 (SPSS, Inc., Chicago, Illinois).

RESULTS

After the implementation of the Nine Ps Protocol, the infection rate among spinal procedures dropped ($p = 0.032$) from 16.7% (Group B) to 3.8% (Group C;) (Table 2). During the study period there was no increase in the infection rate among other major orthopaedic operations in our department (Table 3). During the Group B period there were 752 other orthopaedic procedures, including total hip and knee arthroplasties, with an overall infection rate of 0.6%. An increased infection rate was not recorded in the above-mentioned orthopaedic procedures or the spinal operations in the Department of Neurosurgery.

Considering patient-related factors, the three groups had a similar age and sex distribution and a comparable number of risk factors per patient.

The personnel involved in the patients' care were scrutinized. The senior surgeon's (AC) health status did not change in any way during the period when the infections occurred. Twenty one other members of the medical and nursing personnel were associated with the eight infected patients as assistant surgeons or as scrub and circulating nurses. None of these staff members were involved in more than three of the infected cases. However, during the Group B period, where the number of postoperative infections increased, there was a reduction in the number of trained nurses and care assistants As a result, there were less frequent changes of the patients' sheets, and the conditions of dressing changes were also reported as sub-

TABLE 3. Infection Rates of Spinal and Additional Procedures

	August 2002 through January 2003		February 2003 through July 2003		August 2003 through January 2004	
Patient Characteristics	*Spinal Procedures (Group A)*	*Additional Procedures*	*Spinal Procedures (Group B)*	*Additional Procedures*	*Spinal Procedures (Group C)*	*Additional Procedures*
Number of patients	34	660	22	752	26	616
Number of infections (%)	0 (0)	5 (0.75)	7 (16.7)	5 (0.66)	1 (3.8)	6 (0.97)

TABLE 4. Patient Comparison

Patient Characteristics	Infected		p Value
	Yes n = 8	*No n = 94*	
Median age in years (IQR)	66.5 (43.8–71.0)	47.0 (30.8–62.3)	0.068*
Number of men (%)	5 (62.5)	42 (44.7)	0.465†
Number of diagnoses (%)			0.234†
Scoliosis	1 (12.5)	8 (8.5)	
Herniated disc	0 (0)	31 (33.0)	
Spinal stenosis	1 (12.5)	17 (18.1)	
Removal of implants	0 (0)	8 (8.5)	
Tumor	1 (12.5)	9 (9.6)	
Fracture	2 (25.0)	15 (16.0)	
Spondylolisthesis	2 (25.0)	4 (4.3)	
Various‡	1 (12.5)	2 (2.1)	
Median preoperative length of stay in days (IQR)	5 (2–6)	2 (1–5.5)	0.418*
Number of fusion procedures (%)	8 (100)	57 (60.6)	0.096†
Median time of procedure in hours (IQR)	2.7 (1.6–3.9)	2.0 (1.5–3.7)	0.379*
Median number of patient-related risk factors (IQR)	2 (1–3)	1 (0–2)	0.138*

*Mann-Whitney U test

†Fisher's exact test

‡Kyphosis or discitis

IQR = Interquartile range

optimal. This factor, although not directly measurable, was considered in the final assessment.

The place where the infections occurred also was assessed. The infected patients were not admitted to the same ward and were not operated on in the same operating room. Surface and air samples were obtained from the operating rooms and the results were negative for bacterial colonies. One of the eight infected patients was transferred to the intensive care unit (ICU) postoperatively. Another nine patients during the study period also were transferred to ICU and did not develop postoperative spinal infections. The median preoperative length of stay between the infected and the noninfected patients was 5 days versus 2 days, respectively ($p = 0.418$). One patient with tumors stayed in hospital 13 days before the fusion procedure. This patient eventually developed a postoperative spinal infection. All infected patients had an instrumented posterior fusion (Table 4). The fused segments included the thoracolumbar or lumbosacral region in all cases. No patient receiving a cervical fusion developed a postoperative spinal infection. In two of the infected patients in Group B, the fusion expanded to multiple levels (nine and 13 levels). However, another 10 patients in the same group also had long fusions and did not develop an infection (infection rate 16.7% for long fusions). No operation lasted longer than the expected average duration, according to the type of the procedure (Table 5).

TABLE 5. Median Procedure Duration

Diagnosis	Group A		Group B		Group C		Total		Infected Patients	
	n	*Hours*	*n*	*Hours*	*n*	*Hours*	*n*	*Hours*	*n*	*Hours*
Fracture	2	2.8	9	1.8	6	2.0	17	2.0		1.9
Disc herniation	14	1.3	8	1.3	9	1.5	31	1.4	0	—
Spinal stenosis	6	3.7	6	3.0	6	3.9	18	3.5	1	3.0
Spondylolisthesis	2	3.8	3	1.5	1	4.1	6	3.8	2	2.8
Scoliosis	2	4.6	7	4.8	0	—	9	4.8	1	4.2
Tumor	3	2.0	5	3.2	2	2.6	10	2.9	1	3.2
Removal of implants	4	1.8	2	2.1	2	1.4	8	1.6	0	NA
Various	1	3.6	2	3.2	0	NA	3	3.6	1	2.0
Total	34	2.0	42	2.3	26	2.0	102	2.0	8	2.7

NA = Not applicable

There were more ($p = 0.034$) fusions in Group B than in Groups A and C (Table 2). All fusions with postoperative spinal infections used a rod and screws titanium system. Apart from the metallic implants, other types of material, such as anti-adhesive gels, haemostatic powders and patches, allografts, and interspinous polyetheretherketone (PEEK) implants were used in the infected cases. Finally, in three of the postoperative spinal infections where a spinal decompression took place, an anti-adhesive gel was applied.

The same variety of prosthetic material also has been used in the noninfected patients. Sterility and storage conditions of all inserted prosthetic material were satisfactory. No new type of material was introduced during the outbreak of infections. Six of the eight postoperative spinal infections also had allografts of demineralized human bone matrix inserted intraoperatively.

All patients in Groups A and B received intravenous cefuroxim perioperatively. The regime included 1.5 g on induction of anesthesia and 750 mg 8 and 16 hours postoperatively, respectively. After the review of the infected cases and the identification of the responsible, mainly gram-negative bacteria—an aminoglycoside (1 g amikacin, on induction of anesthesia)—were added to the perioperative prophylaxis. This has remained our routine prophylactic routine during the Group C period to the present. Apart from that, no omitted doses were found on review of the patients' drug charts.

The median number of transfused units in the infected patients was higher ($p = 0.032$) than the noninfected patients (Table 6).

The cultures revealed gram-negative bacteria, probably from the bladder and bowel flora, in six of the eight infected patients. Acinetobacter baumani was the primary isolated micro-organism in three of the postoperative spinal infections. Only one of the postoperative spinal infections was because of Staphylococcus epidermidis. In most patients more than one bacterium was isolated in subsequent cultures (Table 7).

TABLE 6. Transfusion Units

	Infected				
	Yes		No		
Diagnosis	*n*	*Median (IQR)*	*n*	*Median (IQR)*	p Value
Scoliosis	1	0	8	0 (0–0)	
Herniated disc	0	NA	31	0 (0–0)	
Spinal stenosis	1	4	17	2 (1–3)	
Removal of implants	0	NA	8	0 (0–0)	
Tumor	1	12	9	2 (0.5–4)	
Fracture	2	2*	15	2 (0–6)	
Spondylolisthesis	2	2*	4	2 (2–3.5)	
Various	1	2	2	1.5 (0–3)	
Total	8	2 (2–3.5)	94	0 (0–2)	0.032†

*Both patients had 2 transfusion units

†Mann-Whitney U test

IQR = Interquartile range; NA = Not applicable

TABLE 7. Micro-Organisms Isolated from the Pus Cultures

Organism	Number of Cases in Which Organism was Isolated
Acinetobacter baumanni	3
Enterococcus faecalis	2
Escherichia coli	2
Proteus mirabilis	1
Pseudomonas aeruginosa	3
Enterococcus cloacae	1
Klebsiella pneumoniae	1
Klebsiella ocytoca	1
Staphylococcus hemolyticous	2
Staphylococcus epidermidis	3
Providencis settgeri	1

DISCUSSION

Postoperative deep wound infections in spinal surgery are a complication with many origins and their assessment remains challenging.[7] An outbreak of infections in our unit led us to develop a new clinical protocol based on the combination of all known risk factors, termed the Nine Ps Protocol. Its use has resulted in a definite reduction of postoperative spinal infections. The predisposing factors studied were patient-related factors, personnel, place, preoperative length of stay, procedure, prosthetics, prophylaxis (perioperative antibiotics), packed red blood cell transfusions, and pus culture results.

Our study has some limitations. The number of patients studied in each group is relatively small. However, despite the small numbers, differences were found between the infected and the noninfected patients. Secondly, albumin levels and a preoperative urinalysis were not available for some patients, most of whom were operated on urgently. Therefore, some cases of subclinical malnutrition or urinary tract infection may have been overlooked.

Established patient-related factors include malnutrition, smoking, alcohol or drug abuse, obesity, diabetes mellitus, rheumatoid arthritis, bladder and/or bowel incontinence, immunosuppression, steroid therapy, surgery for tumor resection, and infection in remote sites.[2,3,5,7,9,11,12,14,16,18,21,22,25–27,32,33] Whether age alone is an isolated risk factor remains unclear.[4,5,15,21] In our series, the age difference between the infected and the noninfected patients had a trend toward significance.

The possible contribution of the personnel involved in patient care is reported less often.[9] Units responsible for the training of residents and fellows can have inherently increased operating times and therefore higher infection rates.[23] The involvement of young trainees as a relevant risk factor, however, is questioned by others.[30]

The greatest source of infection is airborne bacteria inoculation during surgery.[15,16] Periodical air and surface sample cultures may be valuable to the early identification of virulent bacteria colonies. Sheet-changing and dressing-changing conditions on the wards also are an important factor. Posterior spinal operations in particular, differ from other orthopaedic procedures in that the surgical incision is in direct contact with the bed mattress under the influence of the body weight. This may partially explain the increased incidence of spinal infections in our unit compared with other procedures including arthroplasties.

Prolonged preoperative length of hospitalization on the wards also contributes to increased infection rates.[4,9,32] Patients with colonies of hospital flora bacteria more resistant to antibiotics are more susceptible to infection, which has been reported by other authors.[1,18,23,32]

All our infected cases underwent instrumented posterior spinal fusions involving the thoracolumbar or lumbosacral region. Other authors also have reported increased infection rates among these operations.[14,18] Given the specific indication for surgery in each individual, we do not think that this actually belongs to the plausible contributing factors, though it merits attention during the assessment of postoperative spinal infections.

Prolonged duration of the procedure also is a well-recognized risk factor for a postoperative spinal infection.[2,8,11,16,18,32,33] In our study, the average duration of the infected fusions was 3 hours. This is comparable with the operating times for noninfected patients. Additionally, revision surgery, staged surgery, and the number of the fused segments have been correlated with a higher infection rate in previous studies. [4,11,20,18] Such a correlation was not found in our series.

Prosthetic material generally enhances the postoperative infection rate.[3,31] Although Ti alloys have been reported to yield a lower infection risk, all our infected patients had such implants inserted intraoperatively.[25]

Perioperative antibiotics (24 to 48 hours postoperatively is considered the gold standard)[2,4,9,14,16,21] have been established as routine in all spinal procedures.[10,15] The benefit of prophylactic cephalosporins in spinal surgery has been proven.[10,23,32] The choice of a specific cephalosporin may vary. The isolation of various gram-negative bacteria from the infected wounds urged us to add an aminoglycoside to our scheme, as others do routinely.[25] Finally, when assessing possible risk factors, the chance of omitting antibiotic doses should not be overlooked.[5] In our series, however, this did not occur.

Multiple allogeneic blood transfusions probably have a role in the reduction of the host resistance mechanisms and subsequently the development of a postoperative infection.[17,28,29] Transfusion could have played an important role in our postoperative spinal infections (Table 6). Similar results have been reported in the literature.[5,18] This is one of the few patient-related factors that cannot be assessed preoperatively; therefore it represents a separate category in our protocol.

Surprisingly, only one of the eight infected patients in all groups had a staphylococcus infection. The predilection of S. aureus followed by S. epidermidis in the development of postoperative spinal infections is established in the literature.[2,4,11,13–16,19,21,22,32] Nevertheless, the routine use of prophylactic antibiotics lately has altered the spectrum of the reported organisms causing postoperative spinal infections.[18,24] We had similar findings in our patients, which reinforced the assumption of possible direct inoculation through wound contamination or opportunistic infections from normal skin flora on immune-suppressed hosts.

After the outbreak of postoperative spinal infections and their etiologic assessment, our practice changed in three ways. First, sheets and dressings changing on the wards were supervised closely with emphasis on the frequency and meticulous aseptic techniques; arrangements were made for adequate nursing staff coverage. Secondly, amikacin was added to the perioperative chemoprophylaxis scheme. Finally, patient-related factors were scrutinized preoperatively. Specific attention was paid to factors amenable to risk reducing interventions before surgery, especially in elective cases.

A new protocol that combines all previously known risk factors has been developed in our unit to address the problem of a sudden increase of the infection rate in spinal procedures. It has been constructed in a concise but simple mnemonic manner. Its implementation has led to the identification of isolated risk factors and the definite decrease of the infection rate. We propose its routine implementation as a useful tool in the etiologic assessment of postoperative spinal infections.

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