The WHO surgical checklist has been studied widely, and its use has been proven to reduce complications and mortality in diverse surroundings and surgical specialties, although in neurosurgery there is only limited research on the topic. Depending on the type of neurosurgical operation, various studies suggest that adverse event and mortality rates vary between 2%–73.5% and 0%–2.3%, respectively. Complications may lead to reoperations, with a reported incidence of reoperation rates of 1.5%–4.3%. In our own previous small study, the frequency of reoperation was even higher (14.7%).

The use of the WHO surgical checklist has been proven to reduce surgical morbidity and mortality, but its effect on surgical complications requiring reoperation has not been previously studied. The aim of this study was to determine whether the use of the WHO surgical checklist would have an impact on the number and causes of neurosurgical complications leading to a reoperation.

The authors retrospectively gathered information on all neurosurgical reoperations using hospital discharge data as well as the operations and procedures registry, and tracked all primary neurosurgical operations (n = 175) preceding a complication-related reoperation from 2007 to 2011. There were a total of 5418 neurosurgical operations during the study period. For further analysis of electronic patient records, the primary operations were divided into 2 groups based on the time of the WHO surgical checklist implementation in the authors’ unit: 103 operations before and 72 after the introduction of the checklist. Observed adverse events and reoperations were categorized as preventable or unpreventable, and the actual use of the checklist during each operation was recorded.

The overall rate of preventable complication-related neurosurgical reoperations decreased from 3.3% (95% CI 2.7%–4.0%) to 2.0% (95% CI 1.5%–2.6%) after the checklist implementation. The reoperations were mainly due to wound infections, 46% before and 39% after the checklist. All infection-related reoperations proportioned to all neurosurgical operations (2.5% before vs 1.6% after checklist implementation) showed a significant reduction (p = 0.02) after the implementation of the checklist. In particular, there was a significant decrease (p = 0.006) in the rate of preventable infections associated with reoperations, i.e., 2.2% before versus 1.2% after checklist implementation. The overall adherence to checklist use (the “time out” phase) in neurosurgical operations was 78%, and adherence was 70% in primary operations preceding a complication-related reoperation regarded as preventable.

The implementation of the WHO surgical checklist in neurosurgery was associated with a decrease in complication-related reoperations, especially those due to preventable infection complications, the majority of which were wound infections. The adherence to checklist use in individual operations after the checklist implementation did not appear to have an impact on the results.

**KEY WORDS** surgical safety checklist; adverse event; reoperation; WHO; infection
A reoperation is always a serious and unfortunate complication. To our knowledge, there are no previously published studies of the effect of the WHO surgical safety checklist on the number of complications requiring reoperation. The aim of our study was to determine if the implementation of the WHO surgical checklist had an impact on the occurrence and causes of reoperations due to surgical complications in neurosurgery. For this purpose, we retrospectively analyzed the data of more than 5400 patients who underwent neurosurgical procedures. An additional aim was to detect whether there was a connection between complications and compliance with using the checklist.

**Methods**

**Study Criteria**

The study protocol was approved by the Ethical Committee of the Hospital District of Southwest Finland and accepted by the Chief of the Operative Group of Turku University Hospital. The registry database was formed following national legislation in accordance with the ethical standards outlined in the 1964 Declaration of Helsinki.

We searched the discharge data and the hospital registry for operations and procedures at Turku University Hospital from January 2007 to June 2011 that specified neurosurgical primary operations leading to a reoperation due to a neurosurgical complication. Predetermined ICD-10 diagnosis codes (G00, G03, G04, G06, I20-I22, I46-I50, J15, J16, T80, T81, T84, T85, and T88) and surgical procedure codes based on the Nomesco Classification of Surgical Procedures (AAF20, AAF25, AAF90, AAMxx, AAUxx, AAWxx, ABWxx, AWxxx, NAC92, NAG99, NASxx, NAT20, NAWxx, PAUxx, PAWxx, ZSA00, ZSN00, and ZST00) were searched in the registries to identify all neurosurgical complication-related reoperations. The search resulted in 291 matches from 249 complication-related reoperations (Fig. 1). Electronic patient records for all identified patients were examined, and reoperations that were not associated with a neurosurgical complication or preceding neurosurgery were excluded. In addition, 2 reoperations were excluded because the preceding neurosurgical operation took place more than 10 years previously. These criteria led to the exclusion of 54 reoperations. Of the remaining 195 reoperations, 2 were excluded because the preceding neurosurgical procedure was performed before January 2007. This resulted in 175 reoperations that defined the included complication-related episodes and primary operations; a complication-related episode was considered to begin from the preceding neurosurgical procedure (later referred to as the primary operation), which led to the complication-related reoperation.

The study period of January 2007 to June 2011 was divided into 2 periods based on the date of the primary operation and the implementation of the WHO surgical checklist. The period from January 2007 to April 2009 was defined as the period before the checklist and May 2009 to June 2011 as the period after the checklist. There were 103 episodes before and 72 after the checklist implementa-

**Outcome Variables**

The electronic patient records were manually checked for predetermined adverse events by an independent reviewer not involved in the treatment of neurosurgical patients (M.L.). Considered to be adverse events were infections, bleeding, CSF leakage, shunt complications, errors, and delays in diagnosis and/or treatment. The diagnosis of the primary operation and the time span from the primary operation to the complication-related reoperation were also recorded.

The complications involved in each complication episode leading to reoperation were retrospectively analyzed and categorized as theoretically preventable and unpreventable events, based on a consensus of 2 experienced specialists in neurosurgery (Dr. Rahi and Dr. Kotkansalo). An infection was considered preventable if the contamination or the clinical factors enabling the infection could have been prevented by proper sterile precautions or antibiotic prophylaxis. Other adverse events such as bleeding, CSF leakage, error, and delay were considered preventable when due to suboptimal human action. If the time period between the primary operation and the onset of a complication leading to a reoperation was longer than 4 years, infections and shunt-related complications were considered unpreventable. Infections in patients prone to infections or complications due to contributory factors (such as the arm of the patient’s spectacles) leading to skin erosion and exposure of the shunt system were considered unpreventable. All cases were individually analyzed.

The total number of neurosurgical operations in our hospital during the study period was 2665 before (January 2007–April 2009) and 2753 after (May 2009–June 2011) the checklist implementation. The WHO surgical checklist was introduced in our hospital in May 2009. From the beginning of October 2009, the information on the use of the checklist was available in real time via electronic operating room records. The performing of the “sign in,” “time out,” and “sign out” phases of the checklist are entered separately into the software after using the checklist. We scrutinized these data from the studied primary operations performed after the checklist introduction.

**Statistical Analysis**

Data are described as frequencies and proportions. For proportions, 95% confidence intervals (CIs) were calculated. Even though the data included some patients with 2 separate adverse events, all adverse event episodes were considered independent observations. Therefore, the Fisher’s exact test was performed on all association analyses,
Surgical checklist associated with reduced complications

in which proportions before and after checklist implementa-
tion were compared with primary operation, diagnosis,
complications, and preventable adverse events. Baseline
characteristics (sex, age at the time of primary opera-
tion, age at the time of complication, and time between
primary operation and complication-related reoperation)
were analyzed using the Fisher's exact test or Wilcoxon
rank-sum test; p values < 0.05 were considered statisti-
cally significant (2-tailed). The statistical analyses were
generated using SAS software (version 9.3 for Windows,
SAS Institute).

Results

The demographics and classified primary operations
are presented in Tables 1 and 2, respectively. There were
no significant differences between the groups.

The primary operations leading to complication-relat-
ed reoperations represented 3.9% (n = 103) and 2.6% (n =
72) of 2665 and 2753 neurosurgical operations before
and after checklist implementation, respectively. Of the stu-
died complications, 85% (n = 88) and 75% (n = 54) were
categorized as preventable before and after checklist im-
plementation, respectively (p = 0.12). When calculated ac-
cording to the proportion of the total number of neurosur-
gical operations during the study period (proportioned),
the preventable complications leading to reoperation were
significantly lower after the checklist implementation, i.e.,
3.3% (95% CI 2.7%–4.0%) before versus 2.0% (95% CI
1.5%–2.6%) after implementation.

Classified diagnoses of the complication-related re-
operations are presented in Table 3. Most frequently the
reoperations were caused by wound infections. There
was no statistically significant difference between the
groups in any individual diagnosis. However, the rate of
wound infections as a cause for reoperation was signifi-
cantly higher before (n = 47) than after (n = 28) use of the
checklist, representing 1.8% and 1.0% of the total num-
ber of neurosurgical operations, respectively (p = 0.02).
Also the proportion of preventable wound infection di-
agnoses decreased significantly from 1.7% (n = 44) to
0.8% (n = 23; p = 0.0067) after the implementation of
the checklist.

The reoperations were categorized into preventable (n =
142) and unpreventable (n = 33) according to the pre-
ventability of the complication leading to the reoperation.

FIG. 1. Flow chart showing exclusion and inclusion of the studied neurosurgical complication-related reoperations for the compari-
son analysis.
When examining the distribution of clinical diagnoses (Table 3) there was a significant difference in preventability \((p = 0.01)\). The majority of the operations with a wound infection diagnosis were categorized as preventable \((67\%\) vs \(8\%\), respectively) and they represented a higher proportion of preventable \((47\%)\) versus unpreventable complications \((24\%)\). On the other hand, complications of spinal or other implants \((11\%\) vs \(12\%\), respectively) were relatively more frequently unpreventable \((36\%)\) than preventable \((8\%)\). These results support the internal validity of the assessment of individual patient charts concerning preventability.

The rate of infection-related reoperations decreased significantly after the checklist implementation \((2.5\%\) before vs \(1.6\%\) after implementation, \(p = 0.02\); Table 4). An even stronger association was found when comparing preventable infection complications leading to neurosurgical reoperations \((2.2\%\) before vs \(1.2\%\) after, \(p = 0.006\)). Other adverse events (bleeding, CSF leakage, shunt complications, errors, and delays in diagnosis and/or treatment) did not indicate statistically significant differences before and after the introduction of the checklist, but the number of events was small (Table 4). There were no significant differences in the occurrence of different complications when using the checklist (Table 5).

According to the operating room records (October 2009 to June 2011), the average adherence to performing the time out phase, in which at least the time out phase was performed, was \(78\%\) for all neurosurgical operations after the checklist implementation. At least \(1\) of the \(3\) phases of the checklist was used in \(68\%\) \((n = 49)\) of the studied primary operations since the checklist introduction in May 2009 \((n = 72)\); All phases (sign in, time out, and sign out) were performed in \(73\%\) \((n = 36)\) of these operations, and in an additional \(24\%\) \((n = 12)\) of the operations, at least the time out phase was performed, resulting in \(67\%\) compliance with performing the time out phase \((n = 48)\). In the primary operations leading to a preventable complication \((n = 54)\), any phase of the checklist was used in \(70\%\) \((n = 38)\) of the operations; all phases were performed in \(76\%\) of the operations \((n = 29)\), and at least the time out phase was performed in an additional \(9\) operations; thus the overall compliance with performing time out was \(70\%\) \((n = 38)\) in primary operations preceding a preventable complication.

### Table 1. Demographics of the patients in the studied primary operations before and after checklist implementation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before Checklist</th>
<th>After Checklist</th>
<th>(p) Value</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of operations</td>
<td>103</td>
<td>72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males/females (%)</td>
<td>53 (51.5)/50 (48.5)</td>
<td>31 (43.1)/41 (56.9)</td>
<td>0.29</td>
<td>Fisher’s exact</td>
</tr>
<tr>
<td>Mean age at primary operation ± SD (yrs)</td>
<td>58.0 ± 17.0</td>
<td>55.9 ± 16.4</td>
<td>0.32</td>
<td>Wilcoxon rank-sum</td>
</tr>
<tr>
<td>Mean age at complication-related reoperation ± SD (yrs)</td>
<td>58.2 ± 16.9</td>
<td>56.0 ± 16.4</td>
<td>0.30</td>
<td>Wilcoxon rank-sum</td>
</tr>
<tr>
<td>Mean time between primary operation &amp; complication-related reoperation ± SD (days)</td>
<td>100.4 ± 214.6</td>
<td>34.3 ± 55.0</td>
<td>0.13</td>
<td>Wilcoxon rank-sum</td>
</tr>
</tbody>
</table>

### Table 2. Classified primary operations of the studied neurosurgical complication episodes before and after checklist implementation

<table>
<thead>
<tr>
<th>Primary Operations*</th>
<th>Before Checklist (%)</th>
<th>After Checklist (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extirpation or resection of intracranial tumor</td>
<td>19 (18.5)</td>
<td>18 (25.0)</td>
</tr>
<tr>
<td>Ligation of intracranial aneurysm</td>
<td>4 (3.9)</td>
<td>1 (1.4)</td>
</tr>
<tr>
<td>Trepanation of chronic subdural hematoma</td>
<td>4 (3.9)</td>
<td>3 (4.2)</td>
</tr>
<tr>
<td>Ventriculoperitoneal/ventriculoatrial CSF shunts, endoscopic procedures</td>
<td>25 (24.3)</td>
<td>13 (18.1)</td>
</tr>
<tr>
<td>Cranioplasty</td>
<td>3 (2.9)</td>
<td>8 (11.1)</td>
</tr>
<tr>
<td>Transphenoidal procedures</td>
<td>4 (3.9)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Stereotactic procedures</td>
<td>0 (0.0)</td>
<td>1 (1.4)</td>
</tr>
<tr>
<td>Thoracic and/or lumbar decompression &amp; fusion</td>
<td>11 (10.7)</td>
<td>5 (6.9)</td>
</tr>
<tr>
<td>Cervical decompression &amp; anterior/posterior fusion</td>
<td>7 (6.8)</td>
<td>6 (8.3)</td>
</tr>
<tr>
<td>Lumbar laminectomy or microdiscectomy</td>
<td>13 (12.6)</td>
<td>10 (13.9)</td>
</tr>
<tr>
<td>Cervical laminectomy or foraminotomy</td>
<td>5 (4.9)</td>
<td>1 (1.4)</td>
</tr>
<tr>
<td>Operations for tumors of the spinal cord &amp; nerve roots</td>
<td>6 (5.8)</td>
<td>2 (2.8)</td>
</tr>
<tr>
<td>Angiographic procedure</td>
<td>1 (1.0)</td>
<td>1 (1.4)</td>
</tr>
<tr>
<td>Decompression of cranial nerve</td>
<td>0 (0.0)</td>
<td>1 (1.4)</td>
</tr>
<tr>
<td>Other (implantation of spinal injection device, iatrogenic injury to ventriculoperitoneal shunt during abdominal surgery)</td>
<td>1 (1.0)</td>
<td>2 (2.8)</td>
</tr>
</tbody>
</table>

* No significant difference in a comparison of the distribution of primary operations before versus after checklist implementation \((p = 0.26, \text{Fisher’s exact test})\).
We wanted to focus on this specific patient group to analyze significant morbidity and even increased risk of death. and can be viewed as serious adverse events leading to only represent a small part of postoperative complications range of adverse events. 

To our knowledge this is the first study in which the impact of the WHO surgical safety checklist on the rate and causes of complication-related reoperations has been examined. Our main finding was that the implementation of the checklist in neurosurgical operations, surgical-site infection occurs in 1.1%–4.7% of the operations.12,14,16 In our study, wound infections presented at a rate of 1.0%–1.8%, obtained from the surgical diagnoses associated with complication-related reoperations. The effect of perioperative antibiotic prophylaxis on surgical-site infections is controversial,2,3,9,12,14,22 but the checklist could have had a positive effect on the reduction of infections by enhancing attention to and compliance with the proper timing of prophylaxis. In our institution there is a fixed protocol for antibiotic prophylaxis in neurosurgery. In the present study we did not have the benefit of determining the timing of antibiotic administration from the electronic patient records, and this could be a focus of further studies. In our previous studies on implementation of this checklist in individual operations did not appear to correlate with the occurrence of preventable adverse events, but this result may be biased due to the delay of 5 months between the implementation and the electronic recording of the use of the checklist. Thus, the real use of the checklist may have been higher than depicted by the records in the operating room electronic charts. The checklist use was optional in emergency operations during the first 5 months, which may have reduced the checklist use compliance to some extent, but did not affect the recorded rate of checklist use.

According to previous studies of unselected neurosurgical operations, surgical-site infection occurs in 1.1%–4.7% of the operations.12,14,16 In our study, wound infections presented at a rate of 1.0%–1.8%, obtained from the surgical diagnoses associated with complication-related reoperations. The effect of perioperative antibiotic prophylaxis on surgical-site infections is controversial,2,3,9,12,14,22 but the checklist could have had a positive effect on the reduction of infections by enhancing attention to and compliance with the proper timing of prophylaxis. In our institution there is a fixed protocol for antibiotic prophylaxis in neurosurgery. In the present study we did not have the benefit of determining the timing of antibiotic administration from the electronic patient records, and this could be a focus of further studies. In our previous studies on implementation of this checklist in neurosurgical operations we discovered a systematic error in the timing of antibiotic prophylaxis.11,21 Interestingly, the infection rate declined during the implementation of the checklist, even

### Discussion

To our knowledge this is the first study in which the impact of the WHO surgical safety checklist on the rate and causes of complication-related reoperations has been examined. Our main finding was that the implementation of the surgical checklist for routine use by the neurosurgical operating room teams was associated with a decrease in complication-related neurosurgical reoperations, especially those due to preventable infection-related complications, of which the majority were wound infections.

Previous studies have reported that the use of the checklist reduces the overall rate of adverse events, even mortality, and has a positive impact on communication and teamwork.5,6,11,21,24 Complication-related reoperations only represent a small part of postoperative complications and can be viewed as serious adverse events leading to significant morbidity and even increased risk of death. We wanted to focus on this specific patient group to analyze the impact of checklist usage on the severe end of the range of adverse events.

We found that the proportion of complication-related reoperations decreased significantly after checklist implementation. All infections leading to reoperations, including wound infections, and especially the infections categorized as preventable, decreased significantly after the implementation of the checklist. During the primary operation preceding a complication-related reoperation, the compliance rate in performing the time out phase of the checklist was on the same level as in all neurosurgical operations. Unexpectedly, the lack of adherence to using the checklist in individual operations did not appear to correlate with the occurrence of preventable adverse events, but this result may be biased due to the delay of 5 months between the implementation and the electronic recording of the use of the checklist. Thus, the real use of the checklist may have been higher than depicted by the records in the operating room electronic charts. The checklist use was optional in emergency operations during the first 5 months, which may have reduced the checklist use compliance to some extent, but did not affect the recorded rate of checklist use.

According to previous studies of unselected neurosurgical operations, surgical-site infection occurs in 1.1%–4.7% of the operations.12,14,16 In our study, wound infections presented at a rate of 1.0%–1.8%, obtained from the surgical diagnoses associated with complication-related reoperations. The effect of perioperative antibiotic prophylaxis on surgical-site infections is controversial,2,3,9,12,14,22 but the checklist could have had a positive effect on the reduction of infections by enhancing attention to and compliance with the proper timing of prophylaxis. In our institution there is a fixed protocol for antibiotic prophylaxis in neurosurgery. In the present study we did not have the benefit of determining the timing of antibiotic administration from the electronic patient records, and this could be a focus of further studies. In our previous studies on implementation of this checklist in neurosurgical operations we discovered a systematic error in the timing of antibiotic prophylaxis.11,21 Interestingly, the infection rate declined during the implementation of the checklist, even

### Table 3. Comparisons of complication-related reoperations after primary operations before and after checklist implementation for all reoperations, and reoperations caused by preventable and unpreventable complications

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>All Complication-Related Reoperations</th>
<th>Reoperations Caused by Preventable Complications</th>
<th>Reoperations Caused by Unpreventable Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before Checklist (n = 103)</td>
<td>After Checklist (n = 72)</td>
<td>Before Checklist (n = 88)</td>
</tr>
<tr>
<td>Meningitis</td>
<td>2 (1.9)</td>
<td>0 (0.0)</td>
<td>2 (2.3)</td>
</tr>
<tr>
<td>Empyema/abscess of CNS</td>
<td>3 (2.9)</td>
<td>3 (4.2)</td>
<td>2 (2.3)</td>
</tr>
<tr>
<td>Hemorrhage or hematoma complicating a procedure</td>
<td>14 (13.6)</td>
<td>18 (25.0)</td>
<td>12 (13.6)</td>
</tr>
<tr>
<td>Disruption of wound</td>
<td>11 (10.7)</td>
<td>9 (12.5)</td>
<td>11 (12.5)</td>
</tr>
<tr>
<td>Wound infection (excl. sepsicaemia)</td>
<td>47 (45.6)</td>
<td>28 (38.9)†</td>
<td>44 (50.0)</td>
</tr>
<tr>
<td>Foreign body or substance left following procedure</td>
<td>1 (1.0)</td>
<td>1 (1.4)</td>
<td>1 (1.1)</td>
</tr>
<tr>
<td>Other/unspecified postoperative complication</td>
<td>7 (6.8)</td>
<td>3 (4.2)</td>
<td>6 (6.8)</td>
</tr>
<tr>
<td>Complications of spinal implants or other implants (excl. sepsicaemia)</td>
<td>15 (14.6)</td>
<td>8 (11.1)</td>
<td>7 (8.0)</td>
</tr>
<tr>
<td>Other complication of surgical &amp; medical care</td>
<td>3 (2.9)</td>
<td>2 (2.8)</td>
<td>3 (3.4)</td>
</tr>
<tr>
<td>p values between groups (Fisher’s exact test)</td>
<td>0.65</td>
<td>0.77</td>
<td>0.15</td>
</tr>
<tr>
<td>Adverse Event</td>
<td>All Complication-Related Reoperations Before Checklist (n = 103)</td>
<td>All Complication-Related Reoperations Proportioned to the Total No. of Neurosurgical Operations Before Checklist (n = 2665)</td>
<td>Reoperations Caused by Preventable Complications Before Checklist (n = 170†)</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------------------------------------------------</td>
<td>-----------------------------------------------------------------</td>
<td>---------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>After Checklist (n = 72)</td>
<td>p Value</td>
<td>After Checklist (n = 2753)</td>
</tr>
<tr>
<td>Infections</td>
<td>Yes</td>
<td>66 (64.1)</td>
<td>66 (2.5)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>37 (35.9)</td>
<td>2599 (97.5)</td>
</tr>
<tr>
<td>Bleeding</td>
<td>Yes</td>
<td>26 (25.2)</td>
<td>2693 (99.0)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>77 (74.8)</td>
<td>2727 (99.1)</td>
</tr>
<tr>
<td>CSF leakage</td>
<td>Yes</td>
<td>29 (28.2)</td>
<td>29 (11)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>74 (71.8)</td>
<td>2730 (99.2)</td>
</tr>
<tr>
<td>Shunt complications</td>
<td>Yes</td>
<td>23 (22.3)</td>
<td>25 (26.1)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>80 (77.7)</td>
<td>2739 (99.5)</td>
</tr>
<tr>
<td>Errors</td>
<td>Yes</td>
<td>23 (22.3)</td>
<td>23 (9)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>80 (77.7)</td>
<td>19 (7)</td>
</tr>
<tr>
<td>Delays in diagnosis and/or treatment</td>
<td>Yes</td>
<td>3 (2.9)</td>
<td>3 (0.9)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>100 (97.1)</td>
<td>4 (5.6)</td>
</tr>
</tbody>
</table>

* All p values determined by Fisher’s exact test, with statistically significant p values in boldface.
† Totals include patients with multiple complications.
though the timing error was noticed and corrected first in late 2009. Other checklist-related explanations might be better awareness of patient-related risks, readiness to compensate bleeding, sterile instrument check, and more accurate postoperative prescriptions of antibiotics. During the study period there were no significant changes made in the physical environment, treatment protocols, surgical materials, or dressings that could explain the reduction of infections.

Surgical infection is always a setback. In neurosurgery a simple wound infection may lead to multiple reoperations and long antibiotic treatments, and hence cause greater costs than infections in other surgical specialties. The use of a surgical checklist is simple and inexpensive, and could indirectly save money, redundant work, and suffering of patients. There is a need for surgical checklists in all types of surgery, but especially in neurosurgery.

There are some limitations to our study. The number of studied complication episodes was rather small, yet the total number of neurosurgical operations during the study period was substantial. The small number of cases in many diagnosis groups might limit the power of the study to demonstrate a statistically significant difference. When proportioned to the volume and the standard of neurosurgical care, even the small enhancements are clinically significant.

The reliability of the hospital discharge register as the source of the primary data may be questioned, but the information for our analysis came directly from the electronic medical records instead of having been separately recorded in the discharge register. In this study we concentrated on complications leading to a reoperation. It is very unlikely that a reoperation performed in the operating room would not be recorded in the electronic operations and procedures registry and/or patient records. To avoid a bias due to missing or incorrect codes we used a wide search, without relying only on complication codes, and obtaining other complication-related diagnosis and procedure codes as well. It is theoretically possible that the defined search terms may have missed occasional cases, but the occurrence of this kind of error would have affected both patient groups.

The average use rate of the checklist in all neurosurgical operations during the study period is not directly comparable to our results of the checklist use rate. There was a gap between the introduction of the checklist in May 2009 and the beginning of the recording of checklist use in the electronic operating room records from the beginning of October 2009. Regardless of this gap, we collected the study data with an intent-to-treat principle from the beginning of May 2009, and operations without a record of checklist use were reported as “no use” cases, although the checklist most likely was used to an unknown extent in these operations.

Conclusions

Our study indicates that the occurrence of preventable adverse events as the cause of complication-related reoperations among neurosurgical patients was significantly lower after implementation of the WHO surgical safety checklist. In particular, the proportion of both all and preventable wound-infection diagnoses, and the proportion of all and preventable infections leading to a reoperation, decreased significantly after checklist implementation.

Acknowledgments

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References

5. Haynes AB, Weiser TG, Berry WR, Lipsitz SR, Breizat AH,

Author Contributions
Conception and design: Ikonen, Lepänluoma, Rahi. Acquisition of data: Lepänluoma. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: Ikonen, Lepänluoma, Rahi. Approved the final version of the manuscript on behalf of all authors: Ikonen. Statistical analysis: Liittyineni. Study supervision: Ikonen.

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