An intra-operative splash is a common occurrence in elective knee and hip replacement surgery and can potentially transmit bloodborne diseases, with devastating consequences. This study aimed to quantify the risk of a splash and to assess its correlation with body mass index, duration of surgery and the volume of lavage fluid used.

Between December 2007 and April 2008, 62 consecutive patients (38 women, 24 men) undergoing an elective total knee or total hip replacement (TKR, THR) were recruited into the study (32 TKRs and 30 THRs) after appropriate consent.

A splash occurred in all 62 cases. A THR had a slightly higher risk of a splash than a TKR, but this was not statistically significant (p = 0.27). The correlation between body mass index, duration of surgery and the amount of pulse lavage used with a splash was r = 0.013, (non-significant), r = 0.52, (significant) and r = 0.92 (highly significant), respectively.

A high number of splashes are generated during a TKR and a THR. The simple visor mask fails to protect the surgeon, the assistant or the patient from the risk of a splash and reverse splash, respectively.

Orthopaedic procedures pose a hazard to the operating team by generating splashes. These may contaminate the mucous membranes of the respiratory tract, which may then transmit bloodborne pathogens such as human immunodeficiency virus (HIV), hepatitis B virus (HBV), hepatitis C virus (HCV) and tuberculosis. Risk to the surgical team continues to increase alarmingly because of an increasing prevalence of infected patients in the community. Patients in turn are also exposed to the risk of infection by a mechanism termed reverse splash; the falling of bony particles or tissues into the surgical field after hitting an unsterile visor mask. However, there is very little in the literature to ascertain and quantify the risk of splash in orthopaedic procedures.

This study aimed to estimate the risk of splash in elective total knee and total hip replacements (TKR, THR) and to assess the influence of body mass index (BMI), operative time and quantity of lavage fluid on such occurrences.

Patients and Methods

Between December 2007 and April 2008, 62 patients (38 women, 24 men) who underwent an elective TKR (32) or THR (30) were prospectively enrolled into the study. Patients with bleeding disorders, a history of malignancy, and undergoing revision surgery were excluded. The mean BMI in the TKR and THR cohorts was 27.8 (21.4 to 35.2) and 28.1 (20.1 to 37.2), respectively. The mean operating time was 94.4 minutes (60 to 160) in the TKR cohort and 97.8 minutes (65 to 130) in the THR cohort. The mean amount of lavage fluid used was 1.9 l (0.5 to 3) in the TKR cohort and 1.8 l (0.5 to 4) in the THR cohort. A Kimberley-Clark visor mask (Kimberly-Clark Health Care Limited, Roswell, Georgia) was used as the protective gear for all the procedures (Fig. 1). The visor masks of the surgeon, the first assistant and the scrub nurse were collected at the end of each procedure and the number of splashes on the visor, the mask or the face were recorded for each of them. A transparent sheet having four marked quadrants was applied against the visor and mask to count the number of splashes (Fig. 2). The number of splashes in the...
four quadrants were finally added to give the approximate number of total splash droplets. The splashes on the surgeon’s face were counted individually. Contamination of the surgical wound because of a reverse splash was also recorded as and when observed by the operating team. The operating surgeon, operating time (Figs 3 and 4), volume of lavage fluid used (Figs 5 and 6) and the BMI of each patient were recorded for all the procedures. The Pearson’s and Spearman’s correlation coefficients and t-test were carried out to find the significance of these variables to the number of splashes. A p-value of < 0.05 was considered statistically significant.

Results
A splash occurred in all of the 62 cases that underwent an orthopaedic procedure. The mean number of splashes in the TKR and the THR cohorts was 366.2 (71 to 658) and 423.5 (61 to 1050), respectively (p = 0.27). The total
number of splashes in the 19 cemented THRs was 425.8
(230 to 1050) and in the 11 in the uncemented group was
419.4 (61 to 650), but the difference was not statistically sig-
nificant (p = 0.94). The mean number of splashes on the sur-
geon, the assistant and the scrub nurse in knee and hip
replacements was 195.3 (46 to 368), 170.6 (25 to 290), 0.2
(0 to 4) and 221.2 (38 to 491), 201 (21 to 566), 0.4 (0 to 4),
respectively. There was no statistical difference in the num-
ber of splashes, on the surgeon, the assistant and the scrub
nurse between the two procedures (Table I). There was no
statistical difference between splashes on the surgeon and the
assistant during the procedure (p = 0.24). The correlation
between BMI, duration of surgery and amount of pulse
lavage used with splashes was non-significant (r = 0.013),
significant (r = 0.52, p = 0.0001), and highly significant
(r = 0.92, p = 0.0001), respectively. The operative field was
contaminated because of a reverse splash in five of the pro-
ocedures. On a further two occasions a dried-up splash from
the surgeon’s unsterile visor fell back into the operative field.
Bony missiles generated during sawing of the bone contami-
nated the operative field after ricocheting from the unsterile
visor on three occasions. A splash on the surgeon’s face
occurred during eight and on the assistant’s face on nine pro-
cedures, despite the use of a protective visor.

Discussion

A needle-stick injury and a splash are two important but
preventable mechanisms by which the surgical team may be
exposed to transmission of bloodborne pathogens such as
HBV, HCV and HIV. Tuberculosis may also be transmitted
by exposure of the respiratory tract to pathogens. Although
most health-care workers in developed countries are rou-
tinely immunised for hepatitis B and their titres monitored,
the same may not be true universally. The risk of contract-
ing HIV through exposure of mucous membranes is esti-
mated to be 0.1%.1 Studies have demonstrated that one
viral particle of HIV is enough to allow transmission, which
emphasises the need for stringent personal protection dur-
gen surgical procedures.9

In a prospective study, patients undergoing an invasive
radiological procedure were screened for HCV and
91 (10%) of the 944 patients tested positive. A total of
82 (90%) patients had a positive viraemia, showing a high
potential for cross-contamination through blood contacts.5
Another study showed the presence of active hepatitis B
infection in 55 (18.3%) of 300 patients undergoing dental
extraction.6 In a neurosurgical unit in Poland, 4% of
patients were infected with either HBV, HCV, or HIV.7 It is
therefore prudent that surgeons use appropriate equipment

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Table I. Comparative results of a splash in total hip and total knee replacement (THR, TKR)

<table>
<thead>
<tr>
<th></th>
<th>TKR (n = 30)</th>
<th>THR (n = 32)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (range) total number of splashes in procedure</td>
<td>366.2 (71 to 658)</td>
<td>423.5 (61 to 1050)</td>
<td>0.27</td>
</tr>
<tr>
<td>Mean (range) total number of splashes (surgeon)</td>
<td>195.3 (46 to 368)</td>
<td>221.2 (38 to 491)</td>
<td>0.35</td>
</tr>
<tr>
<td>Mean (range) total number of splashes (assistant)</td>
<td>170.6 (25 to 290)</td>
<td>201 (21 to 566)</td>
<td>0.22</td>
</tr>
<tr>
<td>Mean (range) total number of splashes (scrub nurse)</td>
<td>0.2 (0 to 4)</td>
<td>0.4 (0 to 4)</td>
<td>0.40</td>
</tr>
</tbody>
</table>
to protect themselves from the possible risk of infection. Patients are also susceptible to deep wound infection through a reverse splash. Shedding of particulate material from the surgeon’s skin, mouth or nasal passage has been implicated as a potential cause of infection.9-11 It has been shown that an individual can shed from 5000 to 50,000 particles per minute, which increases with physical activity.10-12

Studies to assess the splash hazard have been carried out in vascular surgery, general surgery and even during dermatological procedures.1-3 Surprisingly, there are no studies in the literature that report on the imminent risk of a splash in orthopaedic procedures. It was evident from our study that the number of splashes is considerably higher than in any of the other specialties,1-3 and it occurred in all the cases. No previous studies have addressed the risk of a reverse splash.1-3 Splashes occurred throughout the surgical procedure, but the use of an oscillating saw for making bony cuts, the use of a pulse lavage, the trial of a prosthesis and implantation of the definitive prosthesis were associated with significantly more splashes. There were slightly more splashes in THR than in TKR, which could be attributed to the relatively bloodless field during a THR because of the use of a tourniquet.

Splashes in the current study, however, may still be under-represented, as the average volume of lavage fluid used in our cases was only 1.8 l, in contrast to the standard recommendation of 4 l of lavage fluid during joint replacements to minimise the risk of third-body wear.13 Furthermore, the number of splashes was possibly lower because the pulse lavage gun was used with a conical shield. The number of splashes may also vary with the position of the patient during a THR, but the lateral position was used in all our patients. Both the operating surgeon and the assistant were at equal risk of a splash in both the procedures, with the operating surgeon having a slightly higher splash count. This could be attributed to the proximity of the surgeon to the operative field. A splash on the scrub nurse occurred in very few procedures, owing to their greater distance from the surgical field.

There are a few limitations to our study. First, the measurement of a splash was relatively crude, and a splash in our study represented only numbers and not the volume or weight of the particulate matter. We did not use techniques to measure the volume or weight of the splash on the visor mask because we did not have the specialised equipment required for this. Nor did we subclassify the splash according to its composition (e.g. blood, saline, fat, etc.). The measurement tool and the technique used in the study to count a splash was aimed to give an approximate number of splashes rather than an absolute value, and may be associated with an inter- and intraobserver variation. The incidence and number of reverse splashes are likely to have been higher than recorded because this was dependent on the objective observations of the surgical team, who would understandably be busy performing the procedure. Despite these limitations, it is evident that THR and TKR generate a huge number of splashes.

The quantity of splashes in orthopaedic joint replacement procedures can be reduced by meticulous operative technique and the cautious use of pulse lavage. Nevertheless, it is impossible to perform a TKR or a THR without causing a splash.

Although the simple visor mask provided adequate protection to the scrub nurse in this study, it failed to protect the operating surgeon and the assistant adequately. A simple visor mask offers no protection from a reverse splash, which can severely compromise the patient’s functional outcome by potentially leading to a prosthetic joint infection.

As a splash is inevitable, it warrants the use of correct protective gear to minimise the risks. Inadequate personal protection may act as a double sword which has the potential to compromise the safety of the surgeon as well as the patient. An enclosed sterile surgical helmet system offers a suitable solution to address this issue. It protects surgeons from potentially infected splashes by providing a circumferential closed cover to the torso and also prevents contamination of the wound and operative field by a reverse splash by virtue of its sterility. The scrub nurse was found to be at a very low risk of splash in our study and is therefore adequately protected by a simple and inexpensive visor mask. Therefore use of a surgical helmet system by the scrub nurse will confer no additional benefits. However, keeping in mind their close proximity to the operative field and the significant risk of a splash, we recommend the operating surgeon and the assistants should routinely use a surgical helmet system.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References