# Risk of Blood Contamination and Injury to Operating Room Personnel

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**The potential for transmission of deadly viral diseases to health care workers exists when contaminated blood is inoculated through injury or when blood comes in contact with nonintact skin. Operating room personnel are at particularly high risk for injury and blood contamination, but data on the specifics of which personnel are at greater risk and which practices change risk in this environment are almost nonexistent. To define these risk factors, experienced operating room nurses were employed solely to observe and record the injuries and blood contaminations that occurred during 234 operations involving 1763 personnel. Overall 118 of the operations (50%) resulted in at least one person becoming contaminated with blood. Cuts or needlestick injuries occurred in 15% of the operations. Several factors were found to significantly alter the risk of blood contamination or injury: surgical specialty, role of each person, duration of the procedure, amount of blood loss, number of needles used, and volume of irrigation fluid used. Risk calculations that use average values to include all personnel in the operating room or all operations performed substantially underestimate risk for surgeons and first assistants, who accounted for 81% of all body contamination and 65% of the injuries. The area of the body contaminated also changed with the surgical specialty. These data should help define more appropriate protection for individuals in the operating room and should allow refinements of practices and techniques to decrease injury.**

MANY HEALTH CARE workers now recognize that blood from infected patients can transmit viral disease through percutaneous inoculation or blood contact with nonintact skin. Although the risk of contracting hepatitis B or C is very high and has been recognized for many years, it is the fear of contracting an HIV infection that has caused far-reaching changes in procedures and devices designed to decrease this risk. Some reports[1-6] have attempted to calculate the magnitude of the risk of contracting HIV infection for those personnel who work in the operating room. The Centers for Disease Control (CDC) have recommended Universal Precautions to decrease this risk, and these have been extended and given the force of law by the Occupational Safety and Health Administration (OSHA). Unfortunately these groups do not have enough factual information from the operating room environment to adequately define the frequency and distribution of blood exposure, or the frequency and causes of needlestick and other injuries. Surgeons and operating room supervisors also need this information to be able to choose adequate protective garments to avoid blood contamination and to devise procedures to avoid injury. The purpose of this study was to quantitatively identify the frequency of blood contamination and percutaneous injury, the causes of injury, and factors that may increase or decrease the risk for individuals during operative procedures.

## Materials and Methods

This study was carried out at two hospitals that serve as tertiary referral centers and are two of the major teaching affiliates of The Medical College of Wisconsin. Most operations were performed with surgical residents and students participating.

Three experienced operating room nurses were employed solely to perform this study. They had no other patient care or administrative responsibilities. The nurses observed all personnel who participated in procedures and documented the distribution of blood exposure on the body and gowns. They looked for injuries that occurred (usually accompanied by exclamation of pain or discom-

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fort by the victim) and documented the possible causes of these injuries.

The study nurse arrived in the operating room 30 minutes before the operation to log in the personnel and begin data collection on the operative procedure. During the operation they recorded adverse occurrences such as needlesticks, blood splashes, and glove tears. At the end of the procedure or when individuals changed gown or gloves, the participants were closely inspected. Any contamination on the outside of the gown was noted and recorded. The nurse then assisted each person in removing their gown and gloves and in the process, everted the gown and inspected the inside for signs of blood strikethrough. The scrub suit, foot and ankle wear, and all exposed areas of skin then were inspected for blood contamination.

The nurse's presence and the study itself were well accepted by the surgeons and other operating room personnel who were being observed because the topic was of interest and concern to all who work in our operating rooms. Questions about how an injury or blood contamination occurred were readily answered.

The nurses chose the operations to be observed to include a wide variety of operations and specialties. They chose procedures ranging from short, small-blood-loss procedures under local anesthesia to long, complex operations with high blood loss. Procedures such as endoscopy, central venous catheter insertion, and simple dressing changes were not included. The observation period ended when the patient had left the operating room and the instruments were removed.

### *Definitions*

*Role.* All personnel were assigned a role based on their position at the operating table and on their function. In almost all cases a staff surgeon and a resident participated in the operation and the role "surgeon" was ascribed to the person performing the majority of the procedure. The other was designated "first assistant." Other roles were more easily defined and were intuitively obvious to an experienced operating room nurse. "Other assistants" were usually junior level surgical residents or medical students who held retractors. "Scrub" was usually a technician trained to assist and manage the sterile instruments. The "circulator" was a nurse who prepared the patient and organized other supplies during the operation, did not wear a gown, and almost always wore gloves.

*Body Contamination.* This was defined as the presence of visible blood (not other fluids) on skin or apparel not removed at the end of the operation. Very small droplets may have been missed because only readily obvious blood was recorded.

*Gown Areas.* These are generally obvious except the "upper chest," which was the area above a line drawn at the axillae, and the "knee," which means the area of the gown from the knee to the bottom of the gown, which is variable in length depending on the height of the person. The "cuff" was limited to the knitted area of the gown at the wrist. Additional areas of blood contamination were the cap, mask, eye glasses, and shoe covers, but these were not considered body contamination.

*Cut, Stick, Splash.* A cut was defined as a linear laceration in the skin regardless of the instrument causing the cut. A stick was caused by a needle and may not have been visible. A major splash event was an unexpected splash or squirt of blood that was high volume and uncontrolled, generally causing at least one person to become contaminated.

### Statistical Analysis

The frequency of contamination events for each role, surgical service, and selected body parts were compared with the corresponding frequency of events that occurred in the remainder of the sample by constructing the appropriate $2 \times 2$ tables and evaluating the Pearson chi square statistics, relative risk, and 95% confidence interval. Where contamination events were evaluated per person or per operation, the number of events occurring were compared with the expected number of events that would have occurred based on the overall frequency of events in the total study sample. The p values for the differences between these expected and observed numbers of events were computed assuming that the observed events follow the Poisson distribution. The association between continuous factors reflecting surgical conditions (duration of operation, estimated blood loss, needles used, and volume of irrigation fluid) and the number of contamination events occurring per operation were evaluated using the Spearman rank correlation.

A multivariate analysis was performed to determine which surgical conditions were associated with increased risk of contamination when the effect of the other surgical conditions were taken into account. A cumulative odds model ordinal logistics regression analysis was performed.[7,8] For this analysis the number of contaminations per operation were divided into five categories corresponding to 0, 1, 2, 3, and 4 or more contamination events per surgery. This categorization was used as the dependent variable in the ordinal logistic analysis using the procedure of SAS V6.06 (SAS Institute, Inc., 1989). The score test for the proportional odds assumption was evaluated to confirm the appropriateness of the ordinal logistic model.

The ordinal logistic model, under the proportional odds assumption, provides an estimate, associated with a predictor variable, of the relative risk (odds ratio) of having an additional contamination event or events (dependent variable) *versus* having a lower level of contamination

events per operation. For the continuous surgical factors with significant association with contamination, the risk associated with being at a higher level of contamination events was computed for an increase in the factor equal to one half of the difference in the value of the factor at the 20th and 80th percentiles of its distribution.

## Results

The study observed 234 separate operations performed by eight specialty services and involved 1763 personnel (Table 1). Overall, 118 of the 234 procedures (50%) resulted in at least one person becoming contaminated. The surgical specialty influenced the risk of an individual becoming contaminated. The specialty with the least body contamination (38%) was general surgery and the greatest was gynecology (75%), excluding the specialties with only a single case each. The number of body areas contaminated during an operation also differed by specialty; the greatest was more than two body areas per operation, encountered in orthopedics operations.

The areas of the body that were contaminated with blood are shown in Figure 1 and show some differences in areas contaminated based on surgical specialty. Procedures in gynecology had a greater risk to an individual of finger contamination than the rest of the specialties (relative risk = 2.07, $p < 0.001$), whereas orthopedics had the least finger contamination (relative risk = 0.39, $p < 0.003$), despite more frequent overall body contamination. Despite the equally high percentage of finger contaminations related to other body site contaminations in the cardiothoracic procedures, the risk to an individual was significantly greater for the gynecologic procedures when the injuries per person were evaluated. Operations done by both general surgery and gynecology services were at high risk for forearm contamination (relative risk = 2.02 and 2.84, $p < 0.03$, respectively). General surgery was at much less risk for face and neck contamination (relative risk = 0.29, $p < 0.002$) whereas orthopedics had much more of this risk (relative risk = 3.8, $p < 0.001$). Uncovered areas of the body (*e.g.*, face and neck) were contaminated more often than areas covered by a gown (*e.g.*, chest and abdomen).

The frequency of body contamination also differed according to the role of those participating in the operation and demonstrates the much greater risk to the surgeon and first assistant (Table 2). These two roles accounted for 81% of all body contaminations and they were contaminated in approximately one third of their operative procedures. The scrub technician, the circulator, and the anesthesiologist all had a very low frequency of contamination.

The time required for the operation also influenced the frequency of body contamination (Table 3). Short operations (<1 hour) were associated with approximately one contamination every five operations, but procedures longer than 5 hours were associated with approximately three contaminations per operation; a 15-fold increase.

The frequency of body contamination increased as the amount of blood lost during the operation increased (Table 4). The greatest number of both personnel and body areas contaminated, however, occurred during operations with blood loss less than 500 mL because more of these were performed. An additional factor that correlated with body contamination was the amount of irrigation fluid used (Spearman correlation = 0.29, $p < 0.0001$).

The injuries and major splash events incurred during operation are listed in Table 5. The surgeon and first assistant were the most frequently injured and splashed. The cause of the cuts in the two first assistants was passing a suture needle. A scrub nurse cut her finger opening a glass ampule, and an anesthesiologist cut his forearm on a sharp piece of equipment. One surgeon was cut while removing a dressing. Only one cut in one surgeon was due to a knife being used for dissection in the wound.

The needlestick injuries were predominantly due to suture needles. Fifteen of the events occurred while suturing, five while loading or unloading a needle holder, and four

TABLE 1. *Risk of Body Contamination by Specialty*

| Service | No. of Operations | Operations with Contamination | % | Body Areas Contaminated | Areas/Operation (mean) |
|---|---|---|---|---|---|
| Cardiothoracic | 42 | 20 | 48 | 43 | 1.02 |
| General | 71 | 27 | 38* | 71 | 1.00* |
| Gynecology | 28 | 21 | 75† | 42 | 1.50 |
| Neurosurgery | 1 | 1 | 100 | 6 | 6.00‡ |
| Orthopedics | 47 | 26 | 55 | 99 | 2.11‡ |
| Transplantation | 1 | 0 | 0 | 0 | 0.00 |
| Trauma | 8 | 4 | 50 | 11 | 1.38 |
| Vascular | 36 | 19 | 53 | 49 | 1.36 |
| Total | 234 | 118 | 50 | 321 | 1.37 |

* $p < 0.05$, compared with the residual group.
† $p < 0.01$, compared with the residual group.
‡ $p < 0.001$, compared with the residual group.

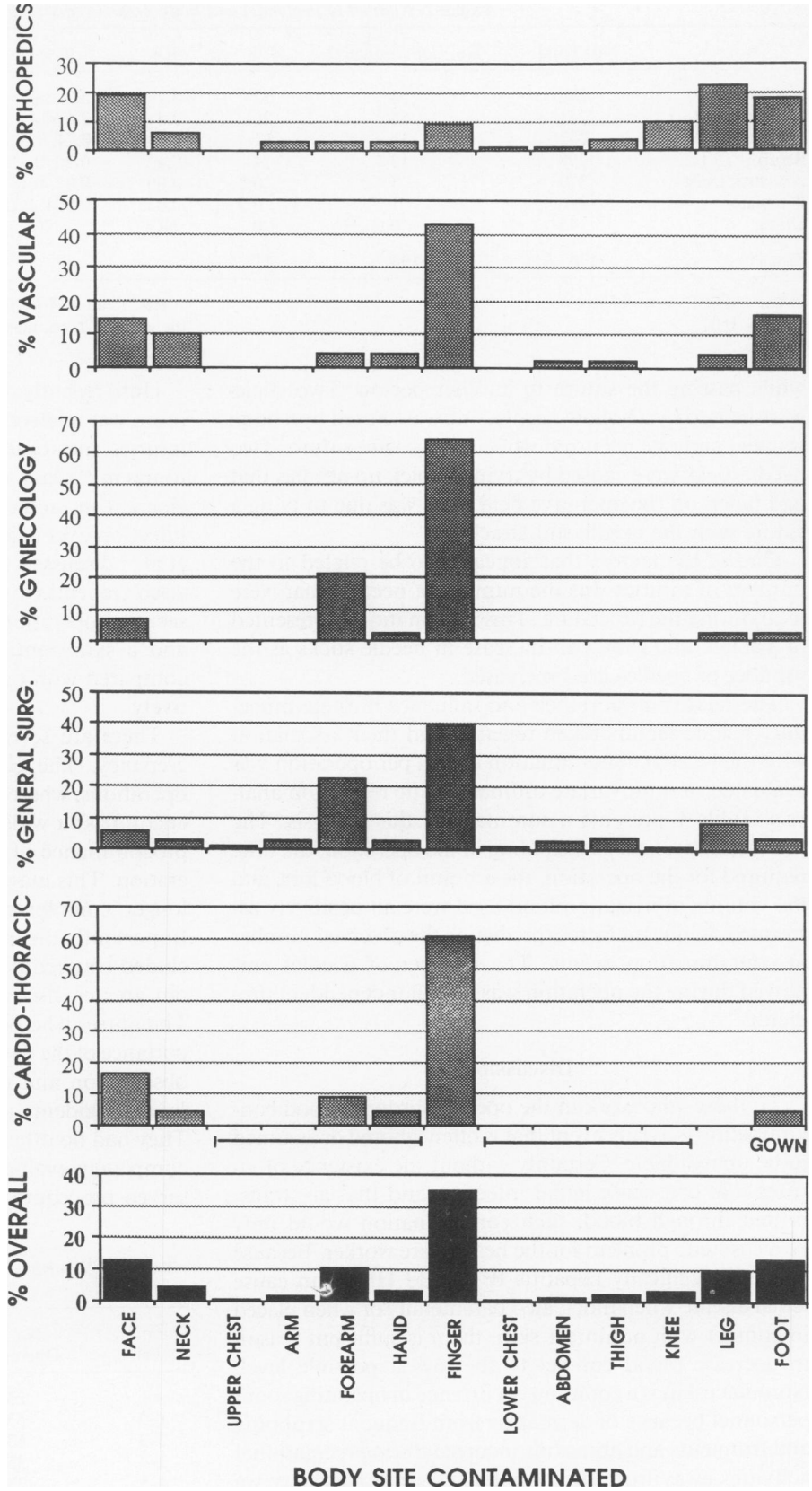


FIG. 1. Distribution of body sites contaminated for each surgical specialty. The values were calculated as the number of contaminations of an area divided by the total number of area contaminations for that specialty × 100. Only specialties with more than 40 areas contaminated were evaluated. Areas covered by the gown are designated by the line above the graph of the overall contamination; values in this area indicate strikethrough of the gown by blood.

TABLE 2. *Number of Personnel and Body Areas Contaminated by Role*

| Role | No. Total | No. Contaminated | % | RR | 95% CI | Areas Contaminated | Areas/Person |
|---|---|---|---|---|---|---|---|
| Surgeon | 246 | 78 | 32 | 4.2 | 3.2, 5.3 | 152 | 0.62* |
| First assistant | 241 | 68 | 28 | 3.4 | 2.6, 4.4 | 107 | 0.44* |
| Other assistant | 267 | 31 | 12 | 1.1 | 0.74, 1.5 | 44 | 0.16 |
| Scrub | 298 | 13 | 4 | 0.4 | 0.20, 0.61 | 13 | 0.04* |
| Anesthsiologist | 370 | 3 | 0.8 | 0.06 | 0.02, 0.18 | 4 | 0.01* |
| Circulator | 296 | 1 | 0.3 | 0.03 | 0.004, 0.18 | 1 | 0.003* |
| Other | 45 | 0 | 0 | NC | NC | 0 | 0† |
| Total | 1763 | 194 | 11 | | | 321 | 0.18 |

* $p < 0.001$.
† $p < 0.01$.

RR, relative risk of contamination compared with the remainder of the group; CI, confidence interval of this risk; NC, not calculable.

while passing the suture to another person. Two sticks were caused by a hollow needle, one was caused by a bone spicule, and one occurred while tying a wire suture. Two needlesticks were caused by trying to pick up needles that had fallen on the operative field. One was due to tying a suture with the needle still attached.

One of the factors that appeared to be related to the number of injuries was the number of needles that were used during the procedure. This information is presented in Table 6 and shows an increase in needle sticks as the number of needles used increased.

The relative importance and influence of these procedure related factors taken together and their association with the level of contamination events per operation was evaluated in multivariate ordinal logistic regression analysis. Table 7 presents a summary of this analysis. The number of persons participating in the operation, the time required for the operation, the amount of blood loss, and the volume of irrigation fluid used were all positively associated significant factors predicting the observed number of contamination events. The number of needles employed during the operation was not an independent predictor.

## Discussion

To those who work in the operating room, blood contamination is a daily event that is often ignored or assumed to be unavoidable. Certainly without the existence of viruses that can cause lethal infection and that are transmitted through blood, such contamination would only be a cosmetic problem for the health care worker. Because viruses (specifically hepatitis B, C, and HIV) can cause lethal disease when inoculated parenterally or when placed in contact with nonintact skin, there is sufficient reason to decrease blood contact to the lowest possible level. Nonintact skin is a common occurrence in operating room personnel because of dermatitis from frequent scrubbing and from cuts and abrasions incurred during recreational activities away from the hospital. To improve safety we have described the frequency of injury and distribution of blood contamination along with the risk factors for individuals who practice in this area.

Until recently literature describing risk in the operating room was relatively sparse[9-11]; a large study of needlestick injuries specifically excluded the operating room environment.[12] Data on these topics, however, is an important element in predicting risk to surgeons of acquiring HIV infection over a lifetime of practice. Recently Gerberding et al.[13] discussed the risk of blood exposure at San Francisco General Hospital after collecting data on 1307 consecutive operations. They found an injury rate of 1.7% and a skin contamination rate of 7.3% of operations, compared with our finding of 15.4% and 50.4%, respectively.

There are several possible reasons for this large discrepancy. The Gerberding study observed consecutive operations, whereas the present study chose operations to encompass a wide distribution of procedures to avoid a predominance of one particular specialty or type of operation. This may have led to a greater preponderance of longer, complex cases than is typical for many hospitals. Importantly the intensity of observation in our study precluded consecutive case observation and probably led to our greater discovery rate of injury and contamination. The nurses who performed this study understood the importance of the data collected. They were trained in careful observation and recording of blood contamination and injury incidents and did not have to rely on memory. They had no other patient care responsibilities and could completely evaluate all personnel at the end of each observed procedure. It is possible therefore that the lower

TABLE 3. *Number of Body Contaminations per Operation Sorted by Duration of Operation*

| Duration (hr) | No. of Operations | Areas Contaminated | Contamination/ Operation |
|---|---|---|---|
| <1 | 25 | 5 | 0.20 |
| 1–2 | 53 | 39 | 0.74 |
| 2–3 | 63 | 92 | 1.46 |
| 3–4 | 35 | 53 | 1.51 |
| 4–5 | 27 | 53 | 1.96 |
| 5–6 | 14 | 52 | 3.71 |
| >6 | 17 | 40 | 2.35 |

Spearman correlation of contaminations with time = 0.44, $p < 0.0001$.

TABLE 4. *Blood Loss Related to Body Areas Contaminated*

| Blood Loss (ml) | No. of Operations | Areas Contaminated | Contaminations/ Operation |
|---|---|---|---|
| <100 | 40 | 29 | 0.73 |
| 100–499 | 132 | 119 | 0.90 |
| 500–999 | 26 | 64 | 2.46 |
| 1000–1999 | 15 | 29 | 1.93 |
| 2000–2999 | 5 | 15 | 3.00 |
| >3000 | 8 | 51 | 6.38 |

Spearman correlation of contaminations per operation with blood loss = 0.40, $p < 0.0001$.

TABLE 6. *Number of Needles Used During a Procedure and Number of Injuries From Needle Sticks*

| No. of Needles Used | No. of Operations | No. of Sticks | Sticks/Operation |
|---|---|---|---|
| <20 | 112 | 4 | 0.04 |
| 20–39 | 56 | 4 | 0.07 |
| 40–59 | 26 | 4 | 0.15 |
| 60–79 | 11 | 7 | 0.64 |
| >80 | 23 | 11 | 0.48 |

Spearman correlation of contaminations per operation with number of needlesticks = 0.3, $p < 0.0001$.

incidence of injury in Gerberding's study was due to under-reporting, which is known to occur.[14]

The existence of policies to alter practice in the operating room is not likely to be a source of the difference between the two studies because our hospital similarly implemented numerous changes 3 years ago to decrease injury, and these have been published elsewhere.[15,16] The incidence of HIV infection is low at our hospital, however. Therefore knowing that the environment is actually dangerous may alter the care with which personnel implement policies and procedures, contrary to the conclusion of Gerberding et al.

Differences in gown and glove use also may have caused a difference in exposure rates. Gerberding et al. described the use of "waterproof" gowns, which were not used in our study because of the discomfort caused by wearing this type of gown. Although they often used double gloves, only the orthopedic service routinely used double gloves at our institution. The much lower incidence of finger contamination in this group in our series strongly suggests that double gloving is an effective practice and should be adopted.

Several other factors alter risk to health care workers in the operating room, and these have important implications for predicting risk, changing practice, and altering behavior.

TABLE 5. *Count of Injuries and Major Splashing Events by Role and Expressed as a Percentage of All Operations*

| Role | Cut (%) | Stick (%) | Splash (%) |
|---|---|---|---|
| Surgeon | 2 (0.9) | 13 (6)* | 15 (6)† |
| First assistant | 2 (0.9) | 6 (3) | 15 (6)† |
| Other assistant | 0 | 4 (2) | 11 (5) |
| Scrub | 1 (0.4) | 7 (3) | 2 (0.9)† |
| Anesthesiologist | 1 (0.4) | 0 | 7 (3) |
| Circulator | 0 | 0 | 3 (1)* |
| Other | 0 | 0 | 1 (0.4) |
| Total | 6 (3) | 30 (13) | 54 (23) |

* $p < 0.001$, compared with the residual group.
† $p < 0.01$, compared with the residual group.
‡ $p < 0.05$, compared with the residual group.
Surgeon and first assistant had a greater incidence of injury, whereas scrub and circulator had a lesser incidence of splashing than the remainder of the group.

### *Influence of Specialty*

There are numerous possible factors that may alter an individual's likelihood of blood contamination during an operation. Among these are the operation being performed, the practices of the team during the operation, the role for the individual, the amount of blood loss, and the protective apparel worn by the individual. Any particular operation occurs too infrequently for useful analysis in this type of study. In addition the specific work practices that increase or decrease risk are too numerous to identify, control, and analyze adequately. Therefore these aspects were assumed to be dependent on the surgical specialty. The influence of surgical specialty on blood contamination of the surgical team is important and is shown in Table 1.

The specialty also influenced the pattern of contamination (Fig. 1) and suggests that certain practices or apparel may be able to improve protection. All specialties are prone to high rates of contamination on the fingers, but this was much less so in orthopedic surgery. The presumed reason for this was the very common use of double gloving by orthopedic surgeons and the lack of this practice in the other specialties. Orthopedic surgeons had increased face and neck contamination due to the splattering of blood from power tools and use of irrigation fluids. This could be altered by additional face protection or other devices to protect from splattering or splashing. This group also had high rates of contamination of legs and feet due to the blood running down the side of the operating table

TABLE 7. *Effect of Change in Surgical Conditions on Risk of Increased Contamination Levels From Multivariate Ordinal Logistic Regression*

| Factor | Unit of Increase | Relative Risk With Increase | p |
|---|---|---|---|
| No. of personnel | 1 person | 1.86 | 0.0001 |
| Duration of operation | 1.5 hr | 1.44 | 0.004 |
| Blood loss | 250 mL | 1.16 | 0.0006 |
| Irrigation fluid | 700 mL | 1.11 | 0.004 |

With each increase of the factor, there is an increase proportionate to the relative risk in the incidence of an additional contamination. For example for each additional 1.5 hr duration of operation, the risk of additional contamination increases by 44%.

and could be prevented by wearing higher leggings or longer, more liquid-resistant gowns. This was not a problem for the cardiothoracic service because the blood loss appeared to be contained in the thoracic cavity. General and gynecologic surgeons often place their hands and arms deeply into the abdomen and cause the high penetration of blood in the forearm area. This may be altered by using impervious materials in this area of the gown.

*Influence of Roles*

Another factor that greatly influenced blood contamination was the role of the individual, as demonstrated in Table 2. The surgeon (whether the staff or the resident) was at the greatest risk for contamination, followed closely by the first assistant. The further away from the wound a person was, the less risk for contamination there was.

*Influence of Blood Loss and Irrigation Fluid*

The amount of blood loss during the procedure also influenced contamination, as shown in Table 4. Although this fact should not be surprising, the finding that the majority of the body contaminations occurred during low (<500 mL) blood loss operations indicates that any procedure represents a potential risk. Therefore necessary protective apparel or procedures should be used routinely and not reserved for the biggest cases.

Contamination also increased as the amount of irrigation fluid increased. This was a factor independent of blood loss or duration of procedure and may relate to additional splashing or to wetting of the gowns with subsequent strikethrough.

*Frequency of Injuries*

Although transmission of viral diseases has occurred through abraded skin, the most dangerous mode of transmission is through percutaneous inoculation by cuts or needle sticks. These occurred most often in the surgeon and first assistant (Table 5). The scrub nurse also received several needle sticks due to the task of loading and unloading needles from the needle holder and passing the instrument to the surgeon.

*Conclusions and Recommendations*

The frequency of blood contamination in the operating room is high, and the distribution of the contamination covers all areas of the body. Therefore adequate protective clothing should be worn to include head covers, goggles, and high shoe covers.

The risk of blood contamination varies with the specialty, and each group should develop policies, procedures, and appropriate apparel to prevent the contamination particular to their procedures.

The surgeon and first assistant are at high risk for blood contamination and should wear the most protective (and often the most expensive and least comfortable) gowns, whereas other assistants and nurses can wear lighter gowns.

The likelihood of body contamination increased as the operative blood loss increased and time of operation increased. When these conditions are predicted, additional precautions should be taken, such as using gowns made with less permeable material, changing gowns more frequently, using sleeve covers or plastic aprons, and frequently inspecting yourself and others for signs of heavy blood contamination. Double gloving also should be used routinely for these operations.

Each institution should have a set protocol for handling sharps and avoiding blood contamination, which is applicable to the operating room environment and which is generally built around the "Universal Precautions" recommended by the CDC.

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