Retained Surgical Sponges: Findings from Incident Reports and a Cost-Benefit Analysis of Radiofrequency Technology

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BACKGROUND: Retained surgical items (RSIs) are serious events with a high potential to harm patients. It is estimated that as many as 1 in 5,500 operations result in an RSI, and sponges are most commonly involved. The adverse outcomes, additional medical care needed, and medico-legal costs associated with these events are substantial. The objective of this analysis was to advance our understanding of the occurrence of RSIs, the methods of prevention, and the costs involved.

STUDY DESIGN: Incident reports entered into the University HealthSystem Consortium (UHC) Safety Intelligence database on incorrect surgical counts and RSIs were analyzed. Reported cases of retained surgical sponges at organizations that use radiofrequency (RF) technology and those that do not were compared. A cost-benefit analysis on adopting RF technology was conducted.

RESULTS: Five organizations that implemented RF technology between 2008 and 2012 collectively demonstrated a 93% reduction in the rate of reported retained surgical sponges. By comparison, there was a 77% reduction in the rate of retained sponges at 5 organizations that do not use RF technology. The UHC cost-benefit analysis showed that the savings in x-rays and time spent in the operating room and in the medical and legal costs that were avoided outweighed the expenses involved in using RF technology.

CONCLUSIONS: Current standards for manual counting of sponges and the use of radiographs are not sufficient to prevent the occurrence of retained surgical sponges; our data support the use of adjunct technology. We recommend that hospitals evaluate and consider the use of an adjunct technology. (J Am Coll Surg 2014;219:354–364. © 2014 by the American College of Surgeons)

Retained surgical items (RSIs) are serious reportable events with a high likelihood of harming patients.[1] Adverse outcomes include pain and suffering, readmission (30% to 59%), reoperation for removal (69% to 83%), infection or sepsis (43%), intra-abdominal abscess, intestinal fistula or obstruction (10% to 22%), visceral perforation (7%), and death (up to 2%).[2,3] More current studies show that RSIs occur at a rate of 1 in 5,500 to 1 in 7,000 operations.[4-6] Surgical items are most commonly retained in the abdomen or pelvis, thoracic cavity, and vagina,[2,3,7] and most often involve surgical sponges.[2-4,6,8] Tissue reaction to retained sponges is much more serious than it is to metal objects and may result in adhesions, encapsulation, and granuloma. More serious reactions involve an inflammatory response, with formation of abscesses and fistulas. This tissue response has led to having sponges migrate into the gastrointestinal tract, bladder, and respiratory tract.[9]

Risk factors associated with RSIs include emergency surgery,[2] high body mass index,[2,6] an unexpected change in the procedure,[2,6] number of major procedures performed,[3] a longer duration of surgery,[6] and incorrect counts.[3,6] Other factors contributing to RSIs include

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Abbreviations and Acronyms
CMS = Centers for Medicare and Medicaid Services
OR = operating room
PSO = Patient Safety Organization
RF = radiofrequency
RFID = radiofrequency identification systems
RSI = retained surgical item
RSS = retained surgical sponge

noncompliance with protocols,[6] poor standards or wound examination,[10] low-quality x-rays,[4,10] unmarked sponges or towels,[10] and poor communication.[4,7,10]

Mandatory reporting and refusal by the Centers for Medicare and Medicaid Services (CMS) to pay for care associated with RSI removal prompted the need for improvement.[11] The medical and legal costs associated with RSIs can be substantial. In 2007, CMS estimated the average cost of removing an RSI at $63,631 per hospital stay.[11] Medical malpractice claims data vary widely, with the larger settlements in the $2 million to $5 million range.[12-14] Depending on the source of the data and the region from which the information was obtained, average indemnity costs in more recent years have ranged from $150,000 to $500,000,[14-16] and the average legal defense costs for physicians are approximately $30,000.[14]

The objective of this analysis was to advance our understanding of why and how RSIs occur, how they can be prevented, and what they cost. Our specific aims were:

1. To describe data entered into the UHC® Safety Intelligence™ incident report tool on incorrect surgical counts and RSIs;
2. To compare the trend in reporting unintentionally retained surgical sponges (RSSs) in organizations that use radiofrequency (RF) technology vs those that do not; and
3. To determine the costs and benefits of adopting RF technology as an adjunct method for preventing RSSs.

There are a number of recommended practices and other technologies for detecting RSIs, including a methodic wound exploration before closure, manual counting, intraoperative radiography, and other technologies used as adjuncts to manual counting. These technologies are not intended to replace manual counting, but rather should be used as a check. These practices, their effectiveness, and their advantages and disadvantages will be described next.

Manual counting procedures

For years the primary intervention for preventing RSSs has been manual counting. Sponges are counted by 2 people before surgery, when they are dispensed onto the sterile field, when wound closure is beginning, and when wound closure is being completed.[17] Counting is time intensive, occupying up to 14% of operative time.[8,15,18] Standard protocols for manual counting are necessary, but are prone to human error. As many as 57 potential failures have been identified in sponge counting,[19] and count discrepancies most often involve a misplaced item, followed by documentation and counting errors.[20,21]

Count discrepancies are common, occurring as often as once in every 8 cases,[5,21] and the odds of an RSI increase by more than 100-fold when a count is discrepant.[5] Perhaps even more important is the evidence showing that correct counts are frequently not reliable. In 62% to 88% of RSI cases, the counts were correct at the end of the procedure.[2,4,6] The sensitivity of counting has been shown to be 77.2%; the specificity, 99.2%; and the positive predictive value, only 1.6%.[5] Resolving a count discrepancy, including radiography when the count cannot be reconciled, can take 13 to 23 minutes, depending on the study.[21,22]

Intraoperative radiography

Radiography has been the primary method of screening for RSI, and best practices include the use of radiopaque (x-ray–detectable) surgical items[16] to facilitate visualization. Although some organizations obtain radiographs on all patients undergoing an open-cavity operation, most use radiography only when the count is incorrect.[2] Radiographs can be expensive and time consuming, they expose the patient to radiation, and they are not always reliable, especially for needles and sponges.[4,8,15] The sensitivity of intraoperative radiographs for detecting a retained item has been found to be 67%,[4] and 10% of radiographs have been found to be falsely negative for radiopaque sponges.[23] The cost of performing routine intraoperative radiography to prevent RSIs is estimated to be $11.5 million for every clinically harmful object detected.[15,24]

Bar-coded counting systems or data-matrix–coded sponges

This computer-assisted counting system consists of 2-dimensional matrix-labeled sponges and a scanning device that reads the labels. Each sponge is individually identified by scanning 1 at a time onto and off of the sterile field. The sponges must be removed from the patient because the scanner cannot read through or detect the presence of a sponge inside the patient.[10,20] Randomized controlled trials have shown that bar coding significantly increased the detection of misplaced and miscounted sponges.[20,25] This technology is reported to be

cost-effective compared with radiography, but it could increase the time spent counting and require time for staff to adapt to using it.[15,20,25]

Radiofrequency detection systems

This technology uses a low-energy RF signal engineered to quickly detect misplaced surgical sponges before and after wound closure. Radiofrequency sponges have a small chip sewn into a pocket in the sponge, but RF does not distinguish the number or a specific sponge. The technology is used at the end of the procedure to supplement manual counts, to determine whether a sponge has been retained inside the patient, or to help locate a missing sponge inside the operating room (OR). Radiofrequency-based technologies typically use a detection mat, or a wand, or a combination of both. The mat, which is placed under the patient on the OR table, reduces the chance of human error with 1-button automatic scanning, and the wand can be passed over the patient, the sterile field, or linen or trash bins/bags to locate a missing sponge. Studies have shown that the RF detection wand is safe and has 100% sensitivity and specificity in identifying retained sponges. It is also faster (detects sponges in less than 3 seconds) and more cost-effective than radiography.[26,27] The wand is slightly more sensitive for detecting sponges in morbidly obese patients than the mat (100% and 97%, respectively).[27] Radiofrequency technology has been shown to be highly effective in quickly reconciling miscounts and detecting retained sponges.[28,29] In 1 large study, no sponges were retained during the 12 months RF technology was being used.[29]

Radiofrequency identification systems

The newest of these products, radiofrequency identification systems (RFIDs), integrate RF sponge detection and identification. In RFIDs, a unique identification chip is sewn into each sponge and provides individual counting and identification from check-in to check-out through a high-energy RF signal. A detection wand also helps locate missing sponges quickly.[28,29] Information on the accuracy and effectiveness of RFID technology is limited, however.[30-32] A clinical feasibility study involving 8 patients found detection accuracy to be 100%, but the sample was too small to draw conclusions.[30]

METHODS

Aggregate incident report data

A retrospective data review was conducted in the UHC Safety Intelligence database, a repository of event reports from more than 100 health care organizations. Several analyses were derived from the incident report data. A review of aggregate counts was conducted on surgical events involving either surgical count issues or RSIs entered into the database in 2011and 2012 by all participating organizations. Surgical count events, including counts that were incomplete, not performed, or incorrect, and RSI events were reviewed by the type of item involved and the frequency of return to the OR to reopen the patient to retrieve a retained item.

Review of descriptions in a subset of incident reports

To improve our understanding of the circumstances surrounding RSS events, we reviewed the narrative descriptions of a subset of reports entered into the UHC Safety Intelligence database by 40 health care organizations participating in the UHC Safety Intelligence Patient Safety Organization (PSO). Event reports that met the following search criteria were reviewed: entered in 2011 and 2012, classified in UHC's taxonomy as an incorrect sponge count or an RSS, and/or retrieved through a text search using the words *sponge* and *retain* or *left in* in the narrative sections of reports. Events categorized as not having reached the patient (near misses) were excluded from the review, because it was assumed that these did not involve an RSS.

Reviewed events were classified in one of the following categories; intentionally retained sponge; unintentionally retained sponge; incorrect count that was not reconciled; incorrect count that was reconciled; and counts that were incomplete or not done. Contributing factors were summarized after the narrative descriptions were reviewed. An unintentionally retained surgical sponge was defined as an event in which the patient's surgical incision was closed and had to be reopened to retrieve the retained sponge, whether it was discovered when the patient was in the OR or afterward. This definition is consistent with that of the Joint Commission.[33]

Comparison of retained surgical sponges at organizations using radiofrequency technology vs nonusers

To understand the impact of RF technology vs other prevention strategies, we compared the trend in the rate of reported unintentionally retained sponges over a 6-year period (2006 to 2012) at 5 organizations using RF technology and 5 organizations that had not implemented the technology. The former had implemented the technology between the last quarter of 2008 and the beginning of 2012. The 5 organizations not using RF technology were matched to the user group by bed size group and region. Organizations represented 4 out of 5 regions in the United States, and the size range was between 300 and 700 beds. Information on the practices for preventing

Table 1. Retained Surgical Items and Surgical Count Events by Type of Item

	Retained surgical item (n = 428)		Surgical count issue (n = 9,467)	
Item type	**n**	**%**	**n**	**%**
Needle	43	10.0	3,792	40.1
Sponge	128	29.9	2,167	22.9
Whole instrument	77	18.0	1,730	18.3
Instrument fragment	171	40.0	167	1.8
Towel	9	2.1	34	0.4
Count incomplete or not done	n/a		1,577	16.7

UHC Safety Intelligence aggregate data from more than 100 participating organizations.
n/a, not applicable.
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RSSs by non-RF users was not collected. All 10 organizations participate in the UHC PSO and the UHC Clinical DataBase/Resource Manager (from which the number of surgical procedures was obtained).

To find incidents of unintentionally retained sponges at these 10 organizations over the 6-year period, we reviewed the narrative descriptions in the event reports. The search criteria for event reports involving surgical sponges were the same as those described in the previous analysis, except that this time near misses were included. The RSS rates per year in each group (RF users vs non-RF users) were calculated per 1,000 surgical procedures. We excluded reports of RSSs that were present on admission.

Cost-benefit analysis

A cost-benefit analysis was conducted for an academic medical center transitioning from radiography to RF technology for sponge detection. Other technologies such as bar coding and RF identification were not included in this analysis because usage was low at organizations that participate in the databases. First, we defined our hypothetical organization, including the number of ORs and the annual number of surgical cases, based on averages obtained from 19 academic medical centers that participate in the UHC Operational Data Base (ODB)/ACTION OI.

Description of the cost-benefit model

A cost-benefit model was developed and it included the costs associated with the use of RF technology (sponge, mat, wand, and wand cover); the cost savings due to a reduction in the use of radiography and the time spent in the OR; and the medical (readmission and surgery) and legal (litigation and settlement) costs avoided by preventing RSSs.

Estimating the costs of radiofrequency technology

The additional costs associated with use of RF technology, including sponges, mats, wands, and wand covers, were calculated. To determine the difference in the cost between x-ray–detectable and RF sponges, purchase data from January 2012 through June 2013 in UHC Spend*LINK* were reviewed. The average cost for x-ray–detectable sponges was calculated from purchase data from all participating hospitals, and the average cost for RF sponges was calculated from purchase data from 13 hospitals that use this technology. The annual cost of the RF wands, wand covers, and mats was obtained from the vendor for academic medical centers that purchase supplies through a group purchasing organization. Information on the percentage of cases for which RF technology is used was obtained from the vendor and from the organizations. The average number of sponges used per case was derived from the literature.

Estimating the cost savings and the costs avoided

Because RF technology is more efficient and effective in finding missing sponges, the cost of OR time and x-rays should drop. To determine the annual savings in x-rays, the cost of a portable x-ray was derived from organizational data and multiplied by the estimated number of count discrepancies annually. The number of discrepancies was determined from an occurrence rate in the literature. To calculate the OR time saved, information on the average time to reconcile a count discrepancy and the cost per minute of OR time was obtained from the literature. The following formula was used: annual savings in OR time equals the number of minutes needed to reconcile a count discrepancy multiplied by the cost per minute multiplied by the number of discrepancies. In addition, using data from the UHC Operational Data Base, we compared the average OR minutes per case at the 5 organizations that had been using RF technology for the longest time with 5 organizations (matched by the number of ORs and operations per year) that do not use such technology. The difference in OR minutes/case was calculated for a 2-year period. There was no adjustment for case mix in this analysis.

To determine the medical and legal costs avoided, information on the average cost of readmission and surgery, as well as malpractice claims, were obtained from the literature. The average number of RSSs annually was calculated from an occurrence rate in the literature.

RESULTS

Findings in the aggregate incident reports

In the first analysis, which was a review of aggregate counts of incident reports entered in 2011 to 2012 by more than 100 organizations, there were 9,467 reports

Table 2. Summary of Events Involving Retained Sponges and Surgical Sponge Count Issues from Event Descriptions

	Sponge Count and retained sponge events (n = 824)	
Category	**n**	**%**
Intentionally retained	525	64
Unintentionally retained	41	5
Counts incorrect and not reconciled	172	21
Count not completed/not done	58	7
Counts incorrect, but reconciled before closure	28	3

Data were derived from 40 organizations participating in the UHC Safety Intelligence Patient Safety Organization.
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entered under UHC's taxonomy categories for incorrect, incomplete, or not completed surgical counts, and 428 events entered under RSIs. Table 1 displays the type of item involved in these events. Needles were the most frequently reported item involved in incorrect counts, but they were less commonly reported as a retained item, probably due to issues involved in detecting needles radiographically. Instrument fragments were the most common RSI. Instrument and instrument fragments (eg, drill bits) accounted for 20% of incorrect count events and 58% of retained items. Broken and missing pieces of instruments can be difficult to find or can go unnoticed. The surgeon might also reasonably determine that retrieving broken and missing pieces of instruments could cause more harm than leaving the fragment in the patient and forgo retrieval. Sponges were the second most frequently reported item involved in both incorrect counts and retained items. Retained sponges and towels accounted for 32% of retained items.

Reporters in cases of incomplete counts, count discrepancies, and/or RSIs are asked whether an emergency procedure was involved and whether the patient had an unplanned return to the OR. For count discrepancies, reporters are asked whether the patient was reopened to retrieve the RSI. This information is inconsistently reported because these questions are optional. In 739 reports involving an incomplete count or a count that was not done, 458 (62%) involved an emergency procedure. However, for incorrect counts and RSIs, 21% and 16%, respectively, involved an emergency procedure.

The patient had an unplanned return to the OR in 16% of events categorized as RSIs (43 of 266). Of these 43 cases, 17 (39.5%) involved a sponge, 17 (39.5%) an unspecified item, 4 (9.3%) an instrument fragment, 3 (7.0%) a whole instrument, and 2 (4.7%) a towel. The patient had an unplanned return to the OR in 3.5% of the events involving count discrepancies and counts not done (189 of 5,426).

For events entered under the incorrect counts category, the patient was reopened to attempt to retrieve the object in 3% of the events reported (130 of 4,253). Patients were most commonly reopened to retrieve a sponge (102 of 130, 78%). Of 1,037 reports on incorrect sponge counts with a response to this question, 10% of patients were reopened to retrieve the sponge; this rate was higher than with other items (0% to 2%).

Findings in the subset of incident reports

To advance our understanding of incidents involving RSSs, the narrative descriptions of events involving a sponge count issue or a retained sponge were reviewed. A thorough search of the PSO database for events involving sponges yielded 824 events during calendar years 2011 and 2012, excluding near-misses.

Intentionally retained sponges

A review of the event descriptions showed that more than half of the events (64%) involved intentionally retained sponges, despite being categorized under the taxonomy as unintentionally retained (Table 2). Sponges are intentionally left in the patient and the incision is left open in cases of bowel edema, severe intra-abdominal infection, hypothermia, and acidosis, as well as to reduce the risk of increased intra-abdominal pressure leading to abdominal compartment syndrome. Abdomens are left open after the initial exploration in about 15% to 18% of trauma patients who undergo an exploratory laparotomy.[34]

For events that we classified as involving intentional retention, count issues were commonly described; for example, the number of packed sponges was often unknown or estimated. Count discrepancies were also described on return to surgery for removal of packed sponges; the number of sponges removed did not match the number of packed sponges recorded at the end of the initial procedure.

Unintentionally retained sponges

Of the 824 events in this dataset, 41 events (5%) involved an unintentionally retained sponge (Table 2). Of these, 28 (68%) were discovered while the patient was still in the OR, but after closure, and the patient was reopened to retrieve the sponge. In some cases, the surgical cavity was described as "closed" and required reopening, but the extent of closure was not specifically stated. It is possible that in some of them the skin was not fully closed. Nine cases (22%) were discovered during hospitalization but after the patient left the OR, and 4 (10%) were discovered after discharge during subsequent care or surgery. Of the events that occurred after

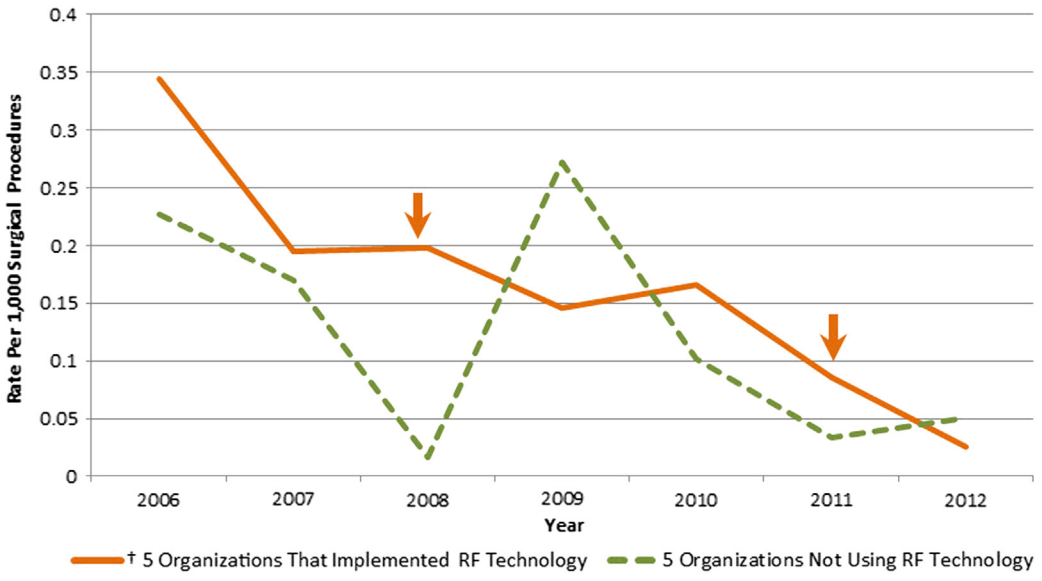

Figure 1. Comparison of retained surgical sponge reporting trends for organizations that use radiofrequentcy (RF) technology and those that do not. †Arrows indicate implementation period for RF technology. (Reprinted from: University HealthSystem Consortium, with permission.)

the patient left the OR, some RSSs were left in for several weeks to many years before they were discovered.

The clinical service was identified in 32 of the 41 events involving an unintentionally retained sponge. Of these, the most common clinical services were obstetrics and gynecology (38%), general surgery (13%), and orthopaedics (9%). In addition to high risk operations involving the abdomen, pelvis, thoracic cavity, and vagina, retained sponges were reported in other areas of the body and in less invasive procedures.

In cases that we classified as involving unintentionally retained sponges, the most common issue (at least 46% of the cases) was that the surgeon continued to close the patient despite noting that the counts were incorrect. Imaging tests were done after closure in the OR or after the patient left the OR, so he or she had to be reopened to retrieve the object either at the time or after a return to the OR. In these RSS cases, counts were more commonly described as discrepant at the end of the procedure rather than falsely correct. In several cases, the counts were correct at the end of the procedure, but subsequent imaging for related or unrelated reasons showed an RSS. In a small number of cases, radiography was performed but was misread.

Incorrect, incomplete, or not completed counts

Of the 824 events, almost 30% described sponge counts that were not reconciled or were incomplete (Table 2). Although the information was not available in all reports, most events indicated that an x-ray was performed when counts were incorrect, incomplete, or not done at all. Sometimes the patient was described as clinically unstable, and the decision was made to forgo reconciling the count discrepancy, or an x-ray was postponed until after the patient was transferred to the ICU—or both. In 3% of the events, incorrect counts were described as being reconciled before closure.

Contributing factors described in the reports

Although factors contributing to count discrepancies and/or RSSs were infrequently explained in event descriptions, the ones that were identified were similar to those found in the literature.[2-6,10,19,29,35] The most frequently described contributing factor, particularly related to counts, was that the procedure was performed on an emergency basis or involved a trauma. Other factors that were noted included an unplanned change to the procedure, staff changes, multiple procedures or a lengthy procedure, the use of a large number of sponges, failure to follow protocol, communications failure, sponges that were cut or were left in the bucket or room from a previous case, and an inappropriate use of sponges (eg, for a laboratory specimen or dressing).

Retained surgical sponge comparisons

A search involving 5 organizations that implemented RF technology between the last quarter of 2008 and the beginning of 2012 yielded 1,008 event reports involving

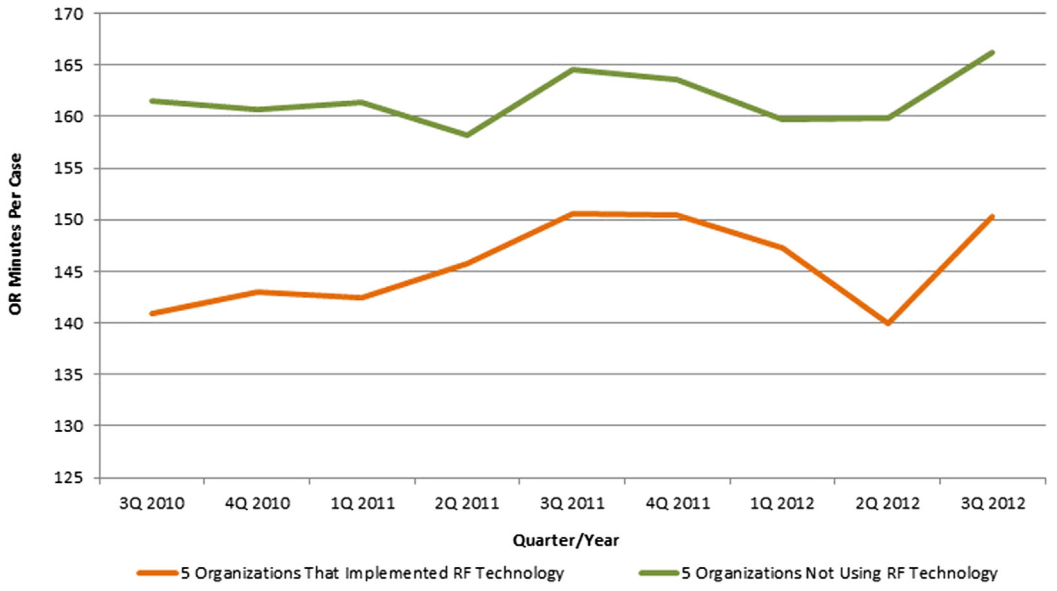

Figure 2. Comparison of operating room time at organizations that use radiofrequency (RF) technology and those that do not. Organizations in the RF technology group implemented the technology between 2007 and 2009. Data on operating room (OR) time before implementation of RF technology are not included. The types of cases in which the technology was used was not available. Data were not adjusted for case mix. (Reprinted from: University HealthSystem Consortium, with permission.)

sponges. Sixty-six cases of unintentionally retained sponges were reported from 2006 through 2012 at these 5 organizations. Next, a comparison was made involving 5 organizations that do not use RF technology. A search for event reports involving sponges yielded 841 reports. Of these, 51 cases of unintentionally retained sponges were reported from 2006 through 2012.

Overall, there was a 93% reduction in the rate of reported RSSs between 2006 and 2012 at organizations using RF technology (Fig. 1). By comparison, for nonusers, there was a 77% reduction in the rate of reported RSSs from 2006 to 2012. The rate of occurrence showed a steady reduction each year for the RF group as each organization began using the technology; the RSS rate per year was variable for the non-RF user group. This variability indicates the results will not likely be sustained.

Radiofrequency technology is highly effective at detecting an RSS, but incidents can occur if the wand is not used in all cases, if RF sponges are not used, or if the wand is not used properly. Failures were described in a few cases, but it was not clear whether there was an equipment failure or whether improper technique was used.

Results of the cost and benefit analysis

Our hypothetical organization had 20 ORs, each of which averaged 560 cases per year, for a total of 11,200. Given a rate of 1% of the cases,[5,29] we determined that our organization would have about 112 incidents of count discrepancies annually. Using an occurrence rate of 1 in 5,500 RSIs,[4] 2 incidents of retained sponges were anticipated annually.

Costs of radiofrequency technology

The additional cost to replace x-ray—detectable sponges with RF sponges would be $0.55 per sponge, and on average, each surgical case would use 30 sponges.[21,22] Therefore, the additional annual cost of transitioning from non-RF sponges to RF sponges for all 11,200 cases was estimated at $184,800. The RF wand requires a new cover for each case at a cost of $1.95. According to reports by the vendor and UHC members, wand usage in surgical cases varied from 20% to 100%, with some reporting use of the wand only in cases of count discrepancies. Depending on the frequency of use, RF wand covers would cost $4,368 to $21,840 annually. For this analysis, UHC calculated the cost of wand covers on 30% of the surgical cases, for a total of $6,552 annually. The cost for the wand and mat equipment varies across organizations depending on their usage. The capital equipment (wands and mats) were provided by the vendor at no cost to the organization based on their high volume purchases of sponges and covers. Therefore, the total additional cost to transition from x-ray detection to RF technology was estimated at $191,352 annually or $17.09 per case.

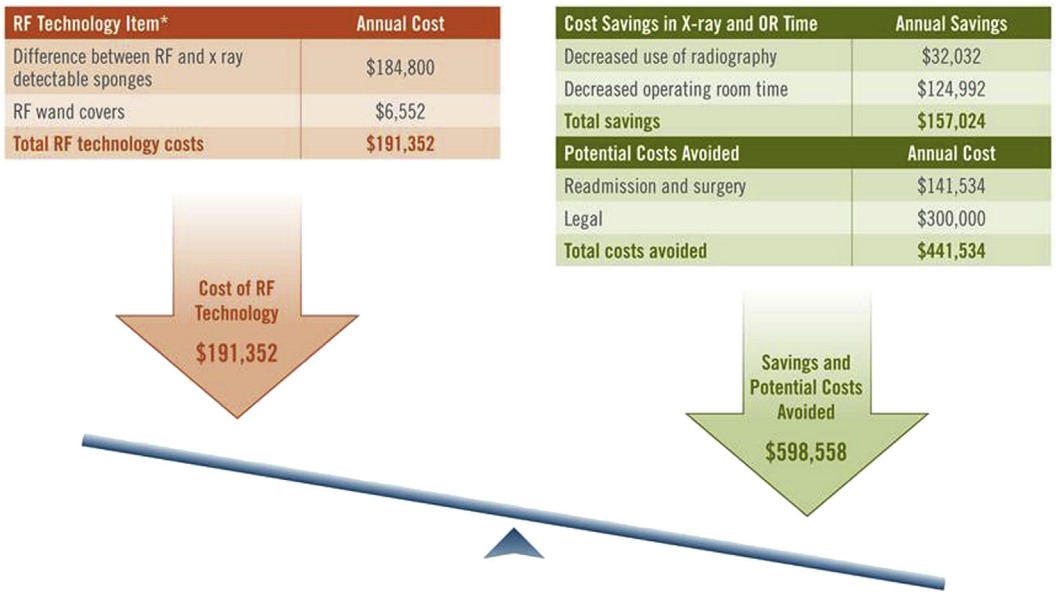

Figure 3. Cost-benefit analysis for the use of radiofrequency (RF) technology. *The cost of the RF mat and wand were not included because of variability in the cost based on product usage. OR, operating room. (Reprinted from: University HealthSystem Consortium, with permission.)

Cost savings

To determine the annual savings in intraoperative radiography, we obtained information from the literature. One organization indicated that the cost of a portable x-ray in the OR was $122,[22] but the total cost with technician time and radiologist fees is likely closer to $450.[24] Taking a conservative approach to the cost of an intraoperative x-ray, we used an average cost of $286 per x-ray. Assuming that a portable x-ray was obtained when there was a count discrepancy (112 cases per year), the annual x-ray cost avoided was estimated at $32,032.

Compared with taking and reading an x-ray, RF technology can mean significant OR time savings because discrepancies can be more quickly resolved. On the basis of findings from 2 studies, we used an average of 18 minutes of OR time saved per case for our cost-benefit analysis; 1 study indicated it takes, on average, 13 minutes to reconcile a count discrepancy, and the other had a finding of 23 minutes.[21,22] Because 1 minute of OR time is estimated to cost $62,[36] the time saved would equal about $1,116 per case, or $124,992 in annual savings for our estimated 112 count discrepancy cases. Therefore, the total annual cost savings in x-ray usage and OR time at our hypothetical organization was estimated at $157,024.

The UHC conducted an additional analysis comparing the average OR time per case at 5 organizations that use RF technology with 5 similar organizations that do not. The data showed that over a 2-year period, OR time for RF users was, on average, about 16 minutes shorter (Fig. 2).

Costs avoided

Medical and legal costs avoided in preventing an RSS through RF detection include readmission and surgery for sponge removal plus litigation and malpractice settlement. With an average medical cost of $70,767 per hospital stay (based on inflation from a CMS estimate of $63,631 in 2007)[11] and conservative settlement costs of $150,000,[14-16] we estimated that 2 avoided RSS incidents would save $141,534 in medical costs and $300,000 in legal costs, for a total of $441,534. Therefore, the costs saved in OR time and x-rays and the costs potentially avoided by preventing an RSS were estimated at $598,558 annually. The benefits of using RF technology, so far, outweigh its cost ($191,352) (Fig. 3).

DISCUSSION

Although counting plays an important role in preventing RSIs, the findings in this analysis and in the literature illustrate the many challenges organizations face. Despite the universal standards for manual counting, incorrect and incomplete surgical counts are common and frequently not reconciled, and RSI incidents persist.[2,20] Efforts to improve organizational performance by enforcing standardized count practices, policy changes, staff education, enhanced collaboration, communication, teamwork, and audits can be effective in reducing RSIs, but have not been shown to eliminate them.[13,28,29,37] Common factors described in the event reports, such as an emergency or

lengthy procedure, are similar to those identified as risk factors in other studies and are difficult to control.[2-6,10,19,29,35]

Despite the risk that an incorrect count could indicate an RSI, our findings show that procedures continued to completion even with incorrect sponge counts, resulting in many unintentionally retained sponges that were discovered after closure, but before the patient left the OR. Yet, once the incision is closed, it is considered an RSI and is a reportable sentinel event.[33] An RSI, even if it is discovered before the patient leaves the OR, results in more OR time, higher costs, and additional risks to the patient. Because most incorrect counts are false alarms, and reconciling counts can take some time, surgeons sometimes disregard them and finish the procedure[6] despite the risk of patient harm. Incorrect final counts should automatically stop the procedure and should be followed by a thorough search for the item inside and outside the body cavity. If the discrepancy is not resolved, further steps should be taken. Radiography is not always accurate in detecting retained sponges.[4,23] In our analysis, we found 2 cases (5%) in which a retained sponge was missed on the x-ray at the end of the procedure and discovered in subsequent imaging.

Because RSIs commonly occur when the count is falsely correct,[2,4-6] relying on correct manual counts is not enough. Further, the practice of using radiographic or adjunct technology only when counts are incorrect is also insufficient. We found that reports often did not have information on whether the final surgical count was correct or not, particularly if the retained sponge was not discovered while the patient was in the OR or soon afterward. Most of the reports that did contain such information involved incorrect counts. Two reports (5%) indicated that the counts at the end of the procedure were falsely correct.

Our analysis on the reporting of RSS over a 6-year period demonstrates that heightened national efforts aimed at preventing RSIs have had a positive effect on reducing the number of retained sponges. Organizations that implemented RF technology demonstrated a greater reduction than the comparison group. The use of RF technology did not eliminate RSSs completely in all organizations, possibly because it was not used for every operation, because operator error was involved, or because non-RF sponges were accidentally used. Organizations need to ensure that RF technology is widely adopted and consistently used, that staff members are educated on its appropriate use, and that non-RF sponges are not used accidentally. Having 2 types of sponges is prone to error. Therefore, removing traditional radiopaque sponges and replacing them with RF sponges eliminates the risk of a retained non-RF sponge. Data on retained sponges support the use RF technology even in areas of the body not commonly identified as at high risk. Adjunct technology should be used in the OR and in labor and delivery, even when the count is correct because manual counts can be falsely correct.

Outcomes of radiofrequency technology at 2 academic medical centers

Other successful outcomes and similar cost-benefit analyses have been described by academic medical centers that implemented RF technology. At the University of Alabama Hospital at Birmingham (UAB), an RSS prevention initiative was spearheaded by a multidisciplinary multilevel team. After an investigation and trials involving several adjunct technologies, the team recommended using RF technology in conjunction with manual counting procedures to prevent RSSs. Radiofrequency technology was selected for its efficiency and effectiveness in detecting and locating missing sponges on and off the sterile field when there are incorrect counts or no time to count; its ability to validate correct counts; and the costs avoided in OR and anesthesia time, unnecessary x-rays, and potential settlements. In the 2 years following RF implementation, there have been no such incidents of RSS.

Similarly, after failed attempts to reduce RSIs by using best-practice guidelines for manual counting, the University of Arizona Medical Center implemented RF technology. In the 2 years before implementation, there were 2 to 3 RSS incidents per year, which included incidents where the sponge count was falsely correct. For more than 5 years, there have been no RSS incidents in the main OR, where RF technology has been used, and RF technology has become the standard of care across this system.

Limitations

This analysis was limited by the voluntary nature of incident reporting, the accuracy of the event categorization, and the lack of complete documentation. Because cases were extracted from a voluntary reporting system, the data might not be representative of all RSI cases, but it provides a large sample. The review of aggregate data for unintentionally retained sponges was complicated by cases being improperly categorized under incorrect counts and other unspecified event types and intentionally retained items being categorized as unintentionally retained. These classification issues demonstrate that a thorough search of the database and an individual review of the event descriptions were necessary to find RSS cases and to identify associated factors. Still, the descriptions at times provided limited information.

Information about the use of RF technology across organizations that implemented it was limited, so some missed RSSs could be due to nonuse. Moreover, we did not know the practices affecting the reduction in RSSs

at the nonuser organizations. Future analyses should focus on comparing the effectiveness of various prevention practices such as RF, RF identification, bar-coding technology, and nonusers of these technologies.

Because we did not adjust for case mix and did not have data on OR time before organizations implemented RF technology, we could not conclude that the lower OR time per case in this group was directly related to the technology.

CONCLUSIONS

Current standards for the manual counting of sponges and the use of radiographs are not sufficient to prevent RSSs. Radiofrequency technology has been shown to be more accurate and effective in detecting and preventing RSSs. The benefits and the estimated costs of using this technology make it an attractive choice for double checking that no sponge is left inside a patient. Hospitals should evaluate and consider the use of adjunct technologies in conjunction with manual counting.

Author Contributions

Study conception and design: Williams, Tung, Steelman, Chang, Szekendi
Acquisition of data: Williams, Tung
Analysis and interpretation of data: Williams, Tung
Drafting of manuscript: Williams, Tung, Steelman, Chang, Szekendi
Critical revision: Williams, Tung, Steelman, Chang, Szekendi

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