Orthopedic Infections

PIN TRACT INFECTIONS:
SILVER VS UNCOATED PINS

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ABSTRACT

To test the hypothesis that coating external fixation pins with a silver-containing compound (Spi-Argent, Spire Corp, Bedford, Mass) will reduce bacterial colonization and/or pin tract infection, 36 silver-coated and 12 conventional stainless steel pins were placed in the iliac crest of six sheep and inoculated with Staphylococcus aureus. After 2½ weeks the pin sites were examined for motion and inflammation, and the pin tips were quantitatively cultured and examined with scanning electron microscopy (SEM). We found that 84% of the uncoated pins were infected, while 62% of the silver-coated pins were infected. Silver-coated pins were less frequently infected than uncoated pins (confidence interval [CI] >85%). Also, silver-coated pins were loose less frequently than uncoated pins. Pin motion was closely correlated with infection: 28 of 32 infected pins (88%) had motion, while only 9 of 16 uninfected pins (56%) had motion (CI >80%). SEM study of the pin tips showed a decreased level of glycocalyx-protected colonization on the surface of the silver-coated pins. Clinically, these results suggest that silver-coated pins will result in less infection and motion at the pin site, the most significant problems in external fixation.

The most common complication in external fixation is pin tract infection, with infection rates commonly reported in the 4% to 12% range.1-3 Furthermore, the pin sepsis rate has changed very little in the past 50 years.1 Pin tract infections decrease the stability of pin anchorage, creating a poor mechanical environment for fracture healing.2-4 Implants are not inert devices; rather, they interact with their surrounding environment.5,6 The majority of orthopedic implants become quickly colonized, most frequently by the flora of the skin, such as Staphylococcus aureus and Staphylococcus epidermidis.5-8 Although colonization may be present without being clinically evident, it is known that the rate of pin tract infection rises proportionally with the length of time that the fixator pins are left in place.9,10 Bacteria become highly adherent to orthopedic devices by secreting a fibrinous glycocalyx which coats the implant's surface.5,6,11 This biofilm provides protection, maximizes nutrition, and supports increased bacterial activity. Lyons et al8 found few or no bacteria in areas of implants without biofilm. Silver has long been known to be a potent antibacterial agent with a very broad spectrum of activity, and has been used safely in medicine for many years,12-15 At the turn of the century, Clayton Parkhill used silver in external fixation; he wrote that his "steel clamp"...is heavily
plated with silver to secure the antiseptic action of that metal."\textsuperscript{15}

By creating a hostile environment on the surface of external fixator pins, one might lessen the intensity of colonization and thus decrease the progression to infection.\textsuperscript{16} This investigation is designed to test the hypothesis that coating a pin with a silver-containing compound (Spiral, Spire Corp, Bedford, Mass) will decrease bacterial colonization. It is a further goal of this study to explore factors relating to infection with external fixator pins.

**MATERIALS AND METHODS**

Four 4 mm stainless steel external fixator pins were placed in each iliac crest of six adult domestic sheep. Three of these pins were plasma-sprayed with a silver containing compound, while the fourth was a conventional stainless steel pin; thus, there were 36 silver-coated pins and 12 standard stainless steel pins. The sheep were premedicated intravenously with 0.12 mg/kg atropine and sedated with 0.6 mg/kg rompen (Xylazine) and anesthetized with 5 mg/kg ketamine. Iliac regions were prepped by shaving and cleansing with povidone-iodine (Betadine) solution. Drapes were placed to isolate the operative field from surrounding contamination. Four stab incisions were made at 1-in intervals in the skin over each iliac crest and the four pins were placed in each crest.

The pins were left protruding from the skin, with one to two sutures placed on either side of the pins if needed for closure. A 1 cc broth solution of type-specific *S aureus* (ATCC #25923) containing $1 \times 10^5$ organisms was injected onto the shaft of the pin below the surface of the skin using a sterile tuberculin syringe. The exposed segment of each pin was protected with sterile gauze, and the iliac regions were covered with a sterile cloth towel that was sutured into place to protect the wound. After 72 hours the wounds were examined and any wound that was not inflamed was reinculated with an additional 1 cc of broth solution containing the $1 \times 10^5$ solution of type specific *S aureus* as before.

After 19 days the sheep were euthanized with an overdose of pentobarbital, and the pin sites were inspected and graded for inflammation and mechanical anchorage. Inflammation was graded from 0 to 3 as the sum of points given for the presence of erythema, heat, and purulent discharge. The pins were graded manually to assess mechanical anchorage, and scored from 0 to 4, where 0 = no motion, 1 = slight motion, 2 = definite motion, 3 = gross motion and 4 = "pulls out by hand."\textsuperscript{11}

The iliac bones were dissected free and the portion of the bone containing the pins was isolated. Pins were removed by advancing them through the bone, to avoid passing them through contaminated tissue. A 1 cm segment was cut from the tip of each pin with a sterile bolt cutter and placed in sterile saline for microbiologic examination. Additional pin segments were also obtained and placed in 10% glutaraldehyde fixative for scanning electron microscopy (SEM). Preparation for microbiologic examination included washing the pin tip in 3 cc of saline, then vortexing the pin segments at high speed in 2 cc saline to remove organisms that were adherent to the surface of the pin. This solution was then used to quantitate the bacterial load by serial dilution technique. The pins were washed again in 5 cc of saline and placed onto tryptic soy agar plates (BBL, Becton-Dickinson Microbiology Systems, Cockeysville, Md) to investigate the possibility of firmed attachment. SEM was performed on the glutaraldehyde-fixed pin segments to analyze the qualitative differences between the silver-coated and uncoated pins.

We examined the relationship between the two sets of pins and the above parameters using chi-square analysis. For this statistical analysis, inflammation was defined by the presence of erythema, heat, purulence, or any combination of these signs (1 or more on the inflammation scale). Motion was determined by "definite" or greater motion (2 or more on the motion scale). Pin data basically fell into one of two groups: 1) highly infected and 2) sterile or minimally colonized. We defined pin infection as greater than $10^4$ organisms present on the pin tips.

**RESULTS**

Infection was the first parameter examined for differences between the two sets of pins. Ten of the 12 uncoated pins (84%) were found to be infected, while 22 of the 36 silver-coated pins (62%) were infected. Thus, there was a strong trend toward silver-coated pins being infected less often than uncoated pins (confidence interval [CI] >85%).

Silver-coated pins were proposed to have a decreased frequency of clinical looseness at their anchor site, due to the diminished influence of infection. We found that 11 of 12 uncoated pins (92%) were unstable in their bony anchorage, while only 27 of 36 coated pins (75%) had gross motion. Thus, coated pins were correlated with stable fixation as compared to uncoated pins (CI >75%).

We also found that 19 of 27 of silver-coated pins with motion were infected (71%), and 10 of the 11 uncoated pins with motion (91%) had infection. Thus, coated pins with motion were less likely to be infected than uncoated pins with motion (CI >85%).
Inflammation was seen in a majority of the pin tracts. The incidence of inflammation in silver-coated and uncoated pins was very similar. Eleven of 12 coated pins (92%) and 34 of 36 uncoated pins (94%) were inflamed (no significant difference).

Furthermore, 10 of 11 (91%) inflamed uncoated pins were found to be infected, while 22 of 34 (64%) inflamed coated pins were infected. Thus, inflamed silver-coated pins are less frequently infected than uncoated pins with inflammation (CI >90%). Furthermore, inflamed silver pins were less likely to have motion than uncoated pins with inflammation. Twenty-six of the 34 inflamed silver-coated pins (76%) were loose on examination, while all 11 inflamed uncoated pins had gross movement at the bone-pin interface. This is significant to CI of greater than 90%.

Motion of the pin has been thought to be highly correlated to infection at the pin site. Independent of surface type, pins without infection were found to be more stable in their bony anchorage than infected pins. Twenty-eight of 32 infected pins had motion (88%), while only 9 of 16 uninfected pins (56%) had motion (CI >80%).

While none (0/10) of the infected uncoated pins were well fixed in bone, 4 of 22 of the infected coated pins (18%) showed no gross motion on examination. Thus, a trend exists for infected coated pins to be more stable than infected uncoated pins (CI >80%).

SEM of the pin tips showed biofilm in varying amounts on the surface of the pins. In the infected pins, bacteria were seen to be intimately associated with this layer. Electron microscopy seemed to show a paucity of bacteria-laden biofilm in the silver-coated pins as compared to the uncoated pins.

**DISCUSSION**

Today, external fixation is used most frequently in fractures associated with soft tissue injury, nerve or vascular trauma, infected fracture sites, compound fractures, and nonunions. These conditions are frequently associated with severely traumatized patients who are often unstable and immunocompromised. In these patients infection can be dangerous.

A majority of pins are colonized early by skin flora. It appears that dormant colonization is common, which with time may progress to outright infection in a significant number of cases. It also has been shown that the rate of infection is directly correlated with the length of time that the pin is in place. By resisting colonization or by decreasing the progression from colonization to infection, a decreased rate of pin tract infection would be expected.

We have proposed that providing a hostile environment for bacteria on the surface of external fixator pins would result in a decreased infection rate at the bone-pin junction. Our data support this hypothesis. We found that only 62% of silver-coated pins were infected, as compared to 84% of uncoated pins (CI >85%).

The two major factors predisposing to pin tract infection are motion at the pin site and tissue necrosis. While the significance of necrosis in contributing to these infections is more obvious, the relationship of a stable bone-pin junction to infection is less clear. Green and Harkess et al reported that motion at the bone-pin junction predisposes to infection. Unwanted motion between the pin and bone may provide a mechanical space—a portal of entry—for microorganisms to access the deep bone space more easily. It also may provoke ongoing local trauma, devitalizing bone and providing a good medium for bacterial growth. Our data support a close relationship between motion and infection. Eighty-eight percent of infected pins were loose, while only 56% of non-infected pins had motion on examination. Thus, infected pins were much more likely to have a loose anchorage than pins without infection. Furthermore, coated pins with infection were more stable than the infected uncoated pins.

Biofilm is composed of secreted bacterial proteoglycans that increase adhesion and encase bacterial "microcolonies" in the glycocalyx. Microbial adherence via this biofilm is a pivotal factor in the infection of implants. It functions to maximize bacterial nutrition, resistance to antibiotics and to the body's immune defenses, and lessen the quantity of inoculum required to establish an infection. In our study, electron micrographs of the pin tips appear to support a decreased level of biofilm-protected colonization in the silver-coated pins as compared to the uncoated pins. However, this was not quantitated.

**CONCLUSION**

External fixation has been performed for nearly a century. However, its use has been limited by the complication of pin tract infection. Our study shows, as Parkhill imagined nearly 100 years ago, that the use of silver-coated pins results in a decreased rate of pin tract infection. Furthermore, the silver-coated pins were more stable at the bone-pin junction than their uncoated counterparts. Silver-coated pins were also found to be more stable when infected, and less frequently infected when loose, as compared to uncoated pins. The clinical usefulness of these findings will require further study; however, preliminarily, our data...
indicate that silver-coated pins will result in less infection and motion at the pin site, the two greatest obstacles in the use of external fixation.

REFERENCES