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Authors

Arora, Jagmeet
Kim, Joshua
Pakvasa, Mikhail
et al.

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Microsurgical Needle Retention Does Not Cause Pain or Neurovascular Injury in a Rat Model

Jagmeet S. Arora, BS*
Joshua K. Kim, BS†
Mikhail Pakvasa, MD‡
Lohrasb R. Sayadi, MD‡
Melinda Lem, MD*
Alan D. Widgerow, MBBCh, MMed§
Amber R. Leis, MD, FACS‡

Background: Approximately 20% of retained foreign bodies are surgical needles. Retained macro-needles may become symptomatic, but the effect of microsurgical needles is uncertain. We present the first animal model to simulate microsurgical needle retention. Given a lack of reported adverse outcomes associated with macro-needles and a smaller cutting area of microsurgical needles, we hypothesized that microsurgical needles in rats would not cause changes in health or neurovascular compromise.

Methods: Male Sprague-Dawley rats ($\bar{x}$ weight: 288.9 g) were implanted with a single, 9.0 needle (n = 8) or 8.0 needle (n = 8) orthogonal to the right femoral vessels and sutured in place. A control group (n = 8) underwent sham surgery. Weekly, a cumulative health score evaluating body weight, body condition score, physical appearance, and behavior for each rat was determined. Infrared thermography (°C, FLIR one) of each hindlimb and the difference was obtained on postoperative days 15, 30, 60, and 90. On day 90, animals were euthanized, hindlimbs were imaged via fluoroscopy, and needles were explanted.

Results: The mean, cumulative health score for all cohorts at each weekly timepoint was 0. The mean temperature difference was not significantly different on postoperative days 15 ($P = 0.54$), 30 ($P = 0.97$), 60 ($P = 0.29$), or 90 ($P = 0.09$). In seven of eight rats, 8.0 needles were recovered and visualized on fluoroscopy. In six of eight rats, 9.0 needles were recovered, but 0/8 needles were visualized on fluoroscopy.

Conclusions: Microsurgical needle retention near neurovascular structures may be benign, and imaging for needles smaller than 8.0 may be futile. Further studies should explore microsurgical needle retention potentially through larger animal models. *(Plast Reconstr Surg Glob Open 2023; 11:e5171; doi: 10.1097/GOX.0000000000005171; Published online 4 August 2023.)*

INTRODUCTION

Intraoperative loss of surgical needles is not uncommon, comprising approximately 20% of retained foreign bodies in a 10-year retrospective review of 49,831 operations.[1] Reports of clinical harm that amount from retained macro-suture needles are scarce, with many sources not reporting any adverse events.[2] Case reports exist suggesting that retained macro-suture needles may cause chronic pain, but some conclusions are confounded by the presence of an additional retained foreign body or the timeline of the patient's symptoms.[3–5] Retained macro-needles may present a possible risk during magnetic resonance imaging, but the authors acknowledge that these are theoretical concerns.[6,7] Imaging techniques, including fluoroscopy and X-ray, are often used to locate retained foreign bodies but can be time-intensive, costly, and ineffective.[2,7–9] For example, a study estimated that the cost of imaging every case to prevent a retained surgical sponge would amount to $1 million for every event it prevents.[10] Microsurgical needles are used in a wide range of surgical procedures, from revascularization to free tissue transfer.[11] These needles are only a few millimeters long, have suture thread thinner than human hair (0.3–0.4 mm), and require the use of high-powered microscopes for visualization.[12] Although the extensive cost of imaging and recovering retained macro-suture needles has been researched, the effects of microsurgical

*From the *School of Medicine, University of California Irvine, Orange, Calif.; †University of California Irvine, Irvine, Calif.; ‡Department of Plastic Surgery, University of California Irvine, Orange, Calif.; and §Center for Tissue Engineering, Department of Plastic Surgery, University of California Irvine, Orange, Calif.*

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needles retained in the body after surgery have not been reported in the literature.

The complication profile of microsurgical needle retention, when compared with macro-suture needles, has not been described.[6] Furthermore, in addition to the costs and radiation exposure associated with imaging, prior literature suggests that imaging may be even more ineffective at detecting the smaller microsurgical needles.[2] A study purposely implanting needles of various sizes in an animal model found that the detection of needles 25 mm or greater in length was 99% compared with 29% for needles 4–10 mm in length.[13] Although prior investigators have advocated for the removal of retained macro-suture needles, they also acknowledge that surgical removal may introduce unnecessary risks such as additional surgical complications and radiation exposure.[14–16] Furthermore, the uncertainty regarding the risk that microsurgical needles pose is reflected in the heterogeneity of hospital policy guiding what procedures are performed, if any, for a missing microsurgical needle. Given this juxtaposition between the potential risks of retained microsurgical needles and the additional resources required in often futile attempts to locate them, a gray area exists in the medical literature regarding evidence-based management of retained microsurgical needles.

Although prior studies have addressed the potential complications of macro-suture needle retention, intraoperative needle retention of any size and its postoperative implications have not been simulated in an experimental model. This study presents the first animal model designed to simulate the clinical effects of a retained microsurgical needle.

We hypothesized that leaving a microsurgical needle near neurovascular structures in rats over 90 days would not produce significant changes in their health or lead to neurovascular compromise. This assertion is supported by prior evidence demonstrating a lack of significant adverse outcomes associated with macro-needle retention and a smaller cutting area of microsurgical needles.[2,16,17] A better understanding of the potential complications of retained microsurgical needles could help improve evidence-based decision-making regarding microsurgical needle retention in the operating room.

Takeaways

Question: We sought to understand the dangers of retained microsurgical needles and determine if imaging modalities could help localize them to provide an evidence-based guide for hospital policy.

Findings: Microsurgical needles were implanted adjacent to the femoral vessels of Sprague-Dawley rats. Experimental groups did not significantly differ in overall health, behavior, IR-thermography, and structural integrity of neurovascular structures over 90 days. Fluoroscopy aided the recovery of 8.0 needles, whereas 9.0 needles were unable to be visualized.

Meaning: Leaving a microsurgical needle in place near neurovascular structures is relatively innocuous, and the additional time spent imaging and searching for needles smaller than 8.0 may be futile.

METHODS

Animals

Sprague-Dawley rats were used as the animal models, as they are a well-recognized tool for microsurgical training.[12,18–21] Furthermore, rat hindlimb anatomy shows remarkable similarities to that of human digits, with vessel sizes that mimic that of free flaps and digital vessels.[22] The femoral artery was selected as the surgical site because it is an easily accessible vessel through a groin incision, and the artery occupies a critical role in perfusion of lower extremity structures.[23,24]

Twenty-four male Sprague-Dawley rats (average weight: 288.9 g, average age: 63 days) were purchased from Charles River (Charles River Laboratories, Raleigh, N.C.). Rats were housed in ventilated cages under normal conditions with a 12-hour light/dark cycle. Animals had free access to standard chow and water. All procedures involving animals were reviewed and approved by the Institutional Animal Care and Use Committee at the University of California, Irvine, California.

Experimental Cohorts

Animals were randomly assigned to one of the three cohorts (9.0 suture needle, 8.0 suture needle, and control), where all cohorts underwent surgery to fully expose the right femoral vessels. The animal was anesthetized with a concentration of 4%–5% isoflurane mixed with oxygen in an induction chamber. Once the animal was deemed to be unconscious, it was transferred to a nose cone to continue the delivery of isoflurane in oxygen and placed in a supine position. The concentration of isoflurane was lowered to 1%–2% isoflurane in oxygen for maintenance. The right inguinal region and dorsal aspect of the right leg were shaved. The area was prepared using aseptic technique, alternating application of betadine, and 70% isopropyl alcohol. Using a scalpel, an S-shaped incision of 2–3 cm was made in the right inguinal region to expose the inguinal fat pad. The inguinal fat pad was then cut along the margin of the open wound and reflected laterally to expose the femoral artery and vein. The common sheath encapsulating the femoral vessels was gently separated using two forceps to better isolate the femoral artery. After the isolation of the femoral artery was complete, the microsurgical needle was prepared for implantation. In experimental cohort 1 (n = 8), a 9.0 taper point needle (needle length = 6 mm) (Sharpoint, Surgical Specialties Corp, Reading, PA) was implanted near the femoral vessel by tying the end of the suture to the femoral fat pad. The distance from the needle tip to the anchor site was standardized to 2 cm. The tip of the needle was then placed directly over and tip orthogonal to the femoral vessels, and the wound was closed in layers using 4.0 Monocryl deep sutures and 4.0 chromic buried simple interrupted sutures. The same procedure was carried out

for experimental cohort 2 ($n = 8$), which was implanted with an 8.0 taper point needle (needle length = 6.4 mm) (Sharpoint, Surgical Specialties Corp, Reading, PA). Finally, the control cohort (n = 8) underwent sham surgery with exposure of the femoral vessels without suture or needle implantation.

Postoperatively, the animals were closely monitored for pain, distress, and discomfort, and were given carprofen (2–5 mg/kg) and buprenorphine (0.01–0.05 mg/kg) via subcutaneous injection once daily for 3 days.

Methods of Assessment

Weekly, each animal underwent a comprehensive health evaluation using a standardized health questionnaire evaluating body weight changes, body condition score (BCS), physical appearance, and behavior.[25–27] Animals were scored by two independent examiners in the above-listed four domains. The independent examiners were not blind to the animal subjects in the experimental and control cohorts. When scoring physical appearance, examiners assessed the quality of grooming and self-care, the presence of ocular discharge, the overall appearance of the limb, and the wound site for evidence of dehiscence, infection, or mutilation. When scoring behavior, examiners assessed the general mobility of the animal, specifically looking for limping or impairments with ambulation, guarding, and vocalizations indicative of pain or distress. Body weight changes, physical appearance, and behavior were scored on a scale of 0–3, with a score of 0 indicating no apparent deviations from normal and 3 indicating severe deviations from normal, relative to the respective category. Similarly, the BCS was scored on a scale of 0–2. Detailed scoring criteria for response variables and BCS are outlined in Figure 1. The health questionnaire score was calculated by summing values from each category for a cumulative score. A total score of three or more, or a max score in a single category would necessitate urgent medical intervention or euthanasia.

To assess limb perfusion, infrared (IR) thermography was performed on postoperative days 15, 30, 60, and 90 using a thermography camera while the animal was anesthetized (FLIR one, Teledyne FLIR LLC, Wilsonville, Oreg.; Fig. 2). Thermographic images of both the operated and contralateral, virgin limb were obtained to draw comparisons.

On postoperative day 90, hind limbs were imaged with fluoroscopy (BV Pulsera Mobile C-Arm, Philips Medical Systems, Eindhoven, the Netherlands). Images were obtained in supine, prone, and lateral decubitus positions in an attempt to visualize the retained microsurgical needles. After imaging, the explantation procedure took place. An S-shaped incision was made in the right inguinal region and the femoral vessels were accessed along the same path as the implantation procedure. Needles were explanted and any capsule or abnormal tissue surrounding the needle, as determined by the senior surgeons, was sent for histological analysis. The femoral vessels were then dissected to the ipsilateral hindfoot to assess the arterial anatomy. A depiction of the study design can be seen in Figure 3.

Euthanasia

Euthanasia was performed via inhalant CO_2 overdose followed by cervical dislocation on postoperative 90. The 90-day timepoint was chosen based on prior literature demonstrating an adequate foreign body response within 12 weeks postimplantation comparable to a chronic foreign body response in humans at a follow-up time of 6 months.[28,29]

Primary and Secondary Outcomes

The first primary outcome was to show no significant difference in the BCS, body weight changes, physical appearance, and behavior between the 8.0, 9.0, and control cohorts using the health questionnaire. The second primary outcome was to demonstrate no significant difference in the infrared thermography temperature obtained with the FLIR one camera between the operated and contralateral, virgin limb at any timepoint (days 15, 30, 60, 90) across the 8.0, 9.0, and control cohorts. Our secondary outcomes included the number of needles visualized on fluoroscopy and the number of needles recovered during dissection on day 90.

Histological Analysis

Extracted tissue was fixed in formalin and embedded in paraffin. Sections were produced from the 5-μm blocks. After deparaffinization and rehydration, the sections were stained using hematoxylin and eosin (H&E) and Masson trichrome. The staining was performed following standard protocols, and the sections were mounted. The resulting sections were imaged at 4× under light microscopy.

Statistics

An estimated sample size of eight rats per cohort was determined after running a power analysis with a power of 80% and an alpha of 0.05. The power calculation was based on previously published data about the average and minimum BCSs in a normal mouse cohort.[26] Analysis was conducted using Microsoft Excel. Means were calculated for each continuous variable by cohort, and cohort means were compared using ANOVA. Ordinal value variables were compared using the Kruskal-Wallis test. Cohen kappa coefficient was used to gauge inter-rater reliability for the standardized scoring system and was calculated in R version 4.2.1 using the irr package.[30,31] A P value of 0.05 was used to determine statistical significance.

RESULTS

Cohen kappa was calculated to be in complete agreement for physical appearance and behavior scores between the raters. For the BCS, Cohen kappa was calculated at 0.817 ($P < 0.001$) for controls, 0.601 ($P < 0.001$) for the 8.0 cohort, and 0.684 ($P < 0.001$) for the 9.0 cohort. Over the course of this experiment, the BCSs had a Cohen kappa of 0.701 ($P < 0.001$). Overall, Cohen kappa scores for inter-rater reliability attested to a high concordance and agreement between reviewers.[32]

A

BCS 1 Emaciated	BCS 2 Under-Conditioned	BCS 3 Well-Conditioned	BCS 4 Over-Conditioned	BCS 5 Obese
				
Segmentation of vertebral column prominent if not visible.	Segmentation of vertebral column prominent.	Segmentation of vertebral column easily palpable.	Segmentation of vertebral column palpable with slight pressure.	Segmentation of vertebral column palpable with firm pressure; may be a continuous column.
Little or no flesh cover over dorsal pelvis. Pins prominent if not visible.	Thin flesh cover over dorsal pelvis, little subcutaneous fat. Pins easily palpable.	Moderate subcutaneous fat store over pelvis. Pins easily palpable with slight pressure.	Thick subcutaneous fat store over dorsal pelvis. Pins of pelvis palpable with firm pressure	Thick subcutaneous fat store over dorsal pelvis. Pins of pelvis not palpable with firm pressure.
Segmentation of caudal vertebrae prominent.	Thin flesh cover over caudal vertebrae, segmentation palpable with slight pressure.	Moderate fat store around tail base, caudal vertebrae may be palpable but not segmented.	Thick fat store over tail base, caudal vertebrae not palpable.	Thick fat store over tail base, caudal vertebrae not palpable.

B

Weight			
0 0-1% weight loss	1 1-10% weight loss	2 10-20% weight loss	3 >20% weight loss
Physical Appearance			
0 Normal	1 Lack of grooming	2 Rough coat, nasal or ocular discharge	3 Very rough coat, abnormal posture
Behavior			
0 Normal	1 Minor changes, like limping	2 Abnormal, reduced mobility, inactive	3 Unsolicited vocalization, self-mutilation, either very restless or immobile
Adapted Body Condition Score			
0 BCS 3-5	1 BCS 2	2 BCS 1	

Fig. 1. Scoring criteria for response variables and body condition score. A, Evaluative criteria for BCS in Sprague-Dawley rats. B, Scoring criteria used for physical examination and analysis.

The average weight gained by postoperative day 15 for the 8.0 cohort was 27.5% ± 18.6%, 33.8% ± 19.8% for the 9.0 cohort, and 24.0% ± 18.8% for the control cohort (P = 0.59). By postoperative day 30, the average weight gain for the 8.0 cohort was 48.3% ± 32.2%, 61.3% ± 27.9% for the 9.0 cohort, and 43.6% ± 35.7% for the control cohort (P = 0.53). The average gained by postoperative day 60 for the 8.0 cohort was 74.9% ± 47.7%, 98.6% ± 42.5% for the 9.0 cohort, and 66.5% ± 52.5% for the control cohort (P = 0.39). The average weight gained by postoperative day 90 for the 8.0 cohort was 90.4% ± 58.0%, 122% ± 52.7% for the 9.0 cohort, and 78.1% ± 62.6% for the control cohort (P = 0.31; Fig. 4A).

The mean, cumulative health score for the 8.0 cohort, 9.0 cohort, and control cohort at each weekly timepoint was 0. The mean temperature difference between the operated leg and contralateral, virgin leg for the 8.0, 9.0, and control cohorts is listed in Table 1. The P value on postoperative day 15 was 0.54, on day 30 was 0.97, on day 60 was 0.29, and on day 90 was 0.09 (Fig. 4B).

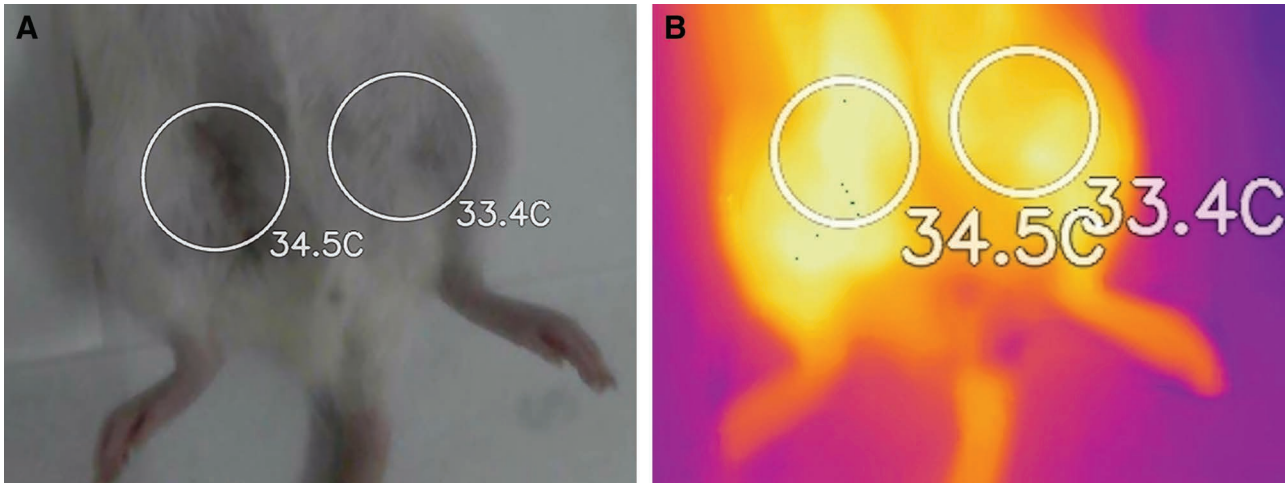

Fig. 2. Infrared thermography analysis of the hind limbs. A, Standard view of the operated (A) and virgin (B) leg in the 8.0 needle cohort on postoperative day 15. B, Infrared thermography view of the operated (A) and virgin (B) leg. Temperatures are averaged over the enclosed circular area and reported in degrees Celsius.

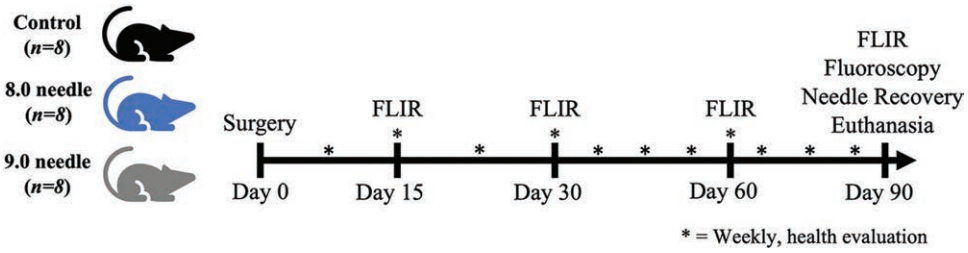

Fig. 3. Study design.

8.0 needles were recovered in seven of eight (87.5%) rats at 90 days and successfully recovered 8.0 needles were visualized on fluoroscopy (Fig. 5A). In contrast, six of eight (75%) 9.0 needles were recovered, and zero of eight (0%) were visualized on imaging (Fig. 5B). Control rats were not subjected to further dissection. Counts for successful visualization and recovery can be seen in Figure 6.

Upon dissection and needle explantation, only one of 16 rats in the 8.0 and 9.0 cohorts was observed to have a capsule around the needle (9.0 needle). In the extracted capsule, H&E staining revealed an increased amount of connective tissue surrounding the opening where the needle was extracted (Fig. 7A, red arrow). Inflammatory cell infiltration was also visualized outside the region where the needle was extracted. As the distance from the needle increased, this region, with increased connective tissue strands, gradually decreased in number and density (Fig. 7A, black box). Outside the zone surrounding the needle, the rest of the tissue contained adipocytes and sections of muscle with normal morphology (Fig. 7B).

Masson trichrome staining demonstrated that the tissue immediately surrounding the needle contained cells with ample protein, such as muscle cells or immune cell deposits, which was abundant with a circumferential and consistent dense layer of cellular infiltration (Fig. 7C, black arrow). Slightly outside the immediately adjacent needle zone, there was a layer of disorganized collagen matrix with interspersed adipocytes and myocytes woven together consistent with scar (Fig. 7C, yellow region). Normal tissue surrounded this area with adipocytes, strands of collagen, muscle, and blood vessels exterior to the zone of scarring (Fig. 7D). Taken together, the stains revealed what appeared to be a foreign body response to the needle that stimulated the beginning of encapsulation with dense collagen scarring.

DISCUSSION

This present study was designed to evaluate the potential harm of retained microsurgical needles in an animal model and ultimately better guide decision-making when these needles are lost in the operating theater. After implantation of microsurgical needles (8.0 and 9.0) orthogonal to the right femoral vessels, Sprague-Dawley rats underwent weekly health assessments, were imaged via fluoroscopy at 90 days, and finally dissected to assess femoral vessel patency and foreign body reaction. All animals had identical recoveries from surgery with and without the presence of a retained microsurgical needle. Experimental cohorts did not significantly differ from the control cohort in body weight, BCS, physical appearance, or behavior. Our team used IR thermography as a surrogate for vascular perfusion, and there was no difference in limb temperature between the experimental and control

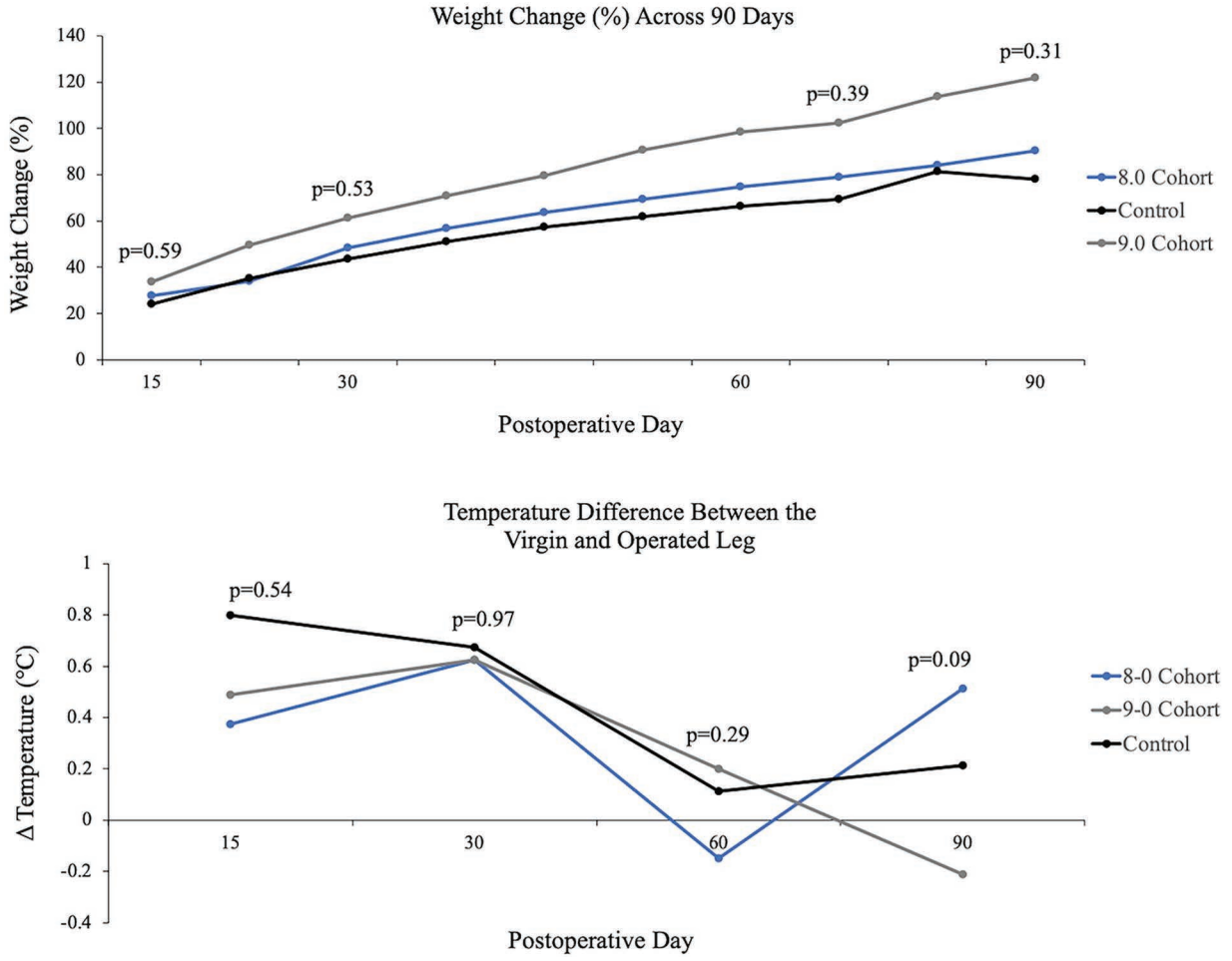

Fig. 4. Weight change and temperature difference across cohorts. A, Weight change (%) relative to baseline tracked across 90 days. B, Temperature difference between the virgin and operated leg across 90 days.

Table 1. Mean Temperature Difference between the Operated and Virgin Leg

Cohort	Postoperative Day			
	15	30	60	90
8.0				
Δ Temperature	0.4±0.3	0.6±0.2	−0.2±0.1	0.5±0.7
9.0				
Δ Temperature	0.5±1.1	0.6±0.3	0.2±0.3	−0.2±0.0
Control				
Δ Temperature	0.8±0.5	0.7±0.2	0.1±0.2	0.2±0.5
***P*-value**	0.54	0.97	0.29	0.09

Δ Temperature = operated leg temperature − virgin leg temperature.

cohorts throughout the study. Additionally, on day 90, evaluation of the femoral vessels revealed no evidence of traumatic vascular pathology, pseudoaneurysm, or fistulas.

The lack of differences between cohorts in limb mobility, weight change, BCS, IR thermography, and anatomical confirmation of femoral vessel patency makes it unlikely that microsurgical needles caused any significant neurovascular injury when retained near the vessels. Although the detrimental effects of foreign body retention, including pain, infection, hemorrhage, and bowel obstruction, have been reported in prior literature, our findings suggest that microsurgical needles may not elicit the same physiological response.[4,5,33] Furthermore, prior studies have suggested that neurovascular injury is a possible complication of macro-needle retention, but also question whether harm or simply a lower incidence of harm should be expected from smaller needles.[2,4–6,34–36] Our study is the first to simulate this intraoperative clinical scenario and offers evidence that microsurgical needle retention may not carry the same risk of adverse effects as previously suggested.

In this study, although nearly all the 8.0 needles were seen on the imaging before anatomical dissection, none of the 9.0 needles were detected. However, the majority of the 9.0 needles and 8.0 needles were recovered during dissection. Although postoperative loss may have been the reason for unsuccessful recovery, it is possible that the needle was missed during dissection. Prior literature supports our difficulty detecting needles smaller than 8.0. In an experimental study evaluating the efficacy of portable X-rays for the identification of surgical needles of various sizes, operating room staff only located needles less

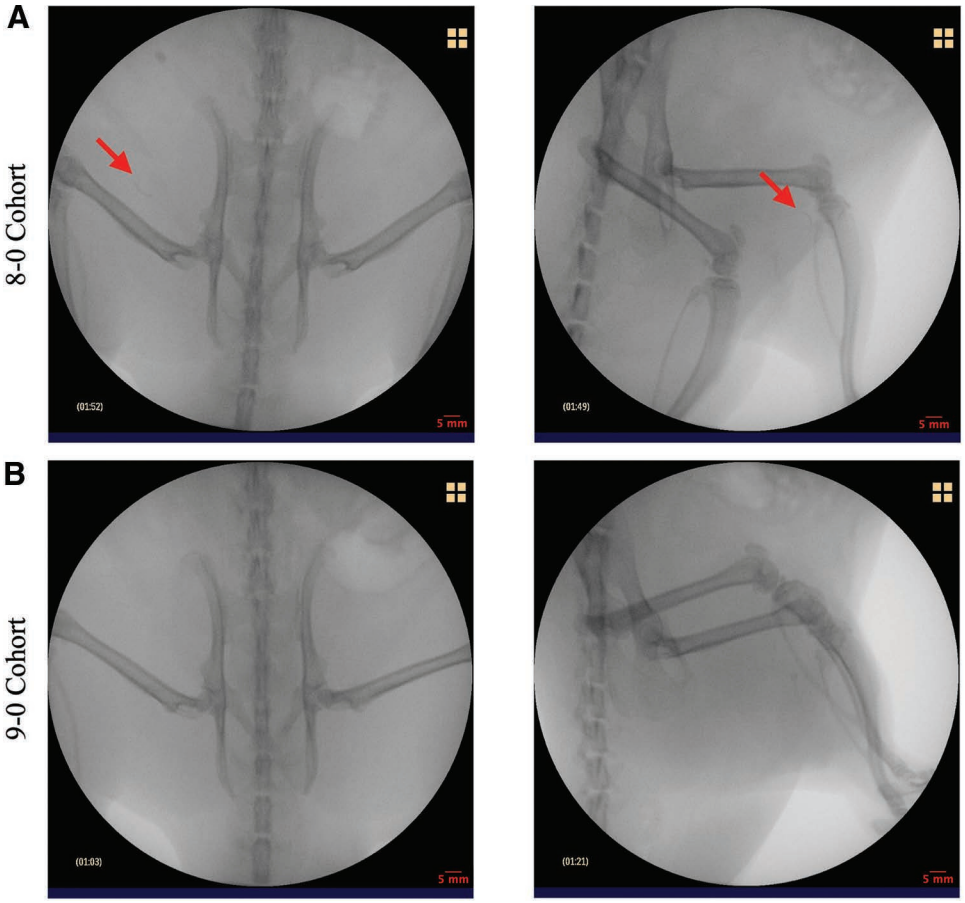

Fig. 5. X-ray images of rats in the (A) 8.0 cohort and the (B) 9.0 cohort in both the supine and lateral decubitus positions. Red arrows indicate where needles were visualized.

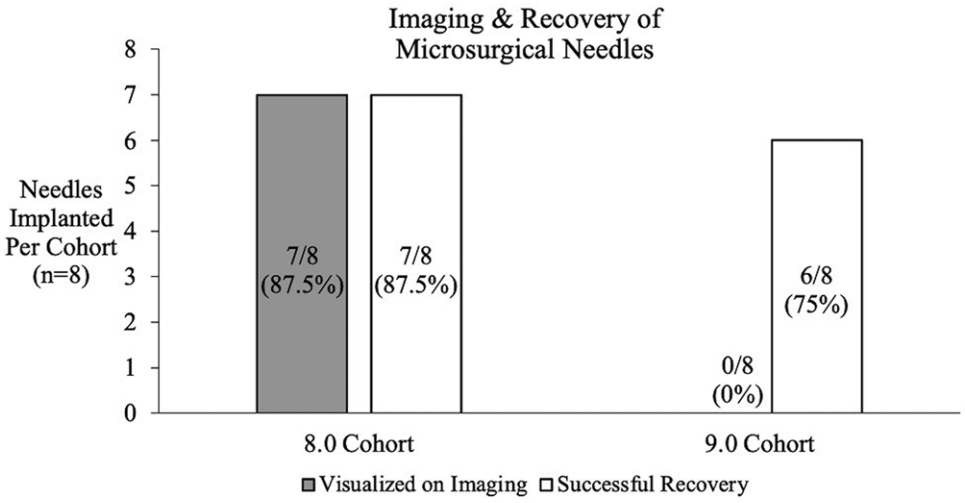

Fig. 6. Counts for the successful visualization and recovery of implanted microsurgical needles in the 8.0 and 9.0 cohorts.

than 13 mm only 13% of the time, and needles measuring 10 mm 0% of the time.[9] The typical size of a 9.0 and 8.0 needle is 6 mm and 6.4 mm, respectively, well below the 10 mm limit identified in the study. Under C-arm fluoroscopy, experienced plastic surgeons found microsurgical needles less than 5 mm only 7.1% of the time.[2] This study, in the context of prior literature demonstrating difficulty finding needles below 10 mm, helps confirm

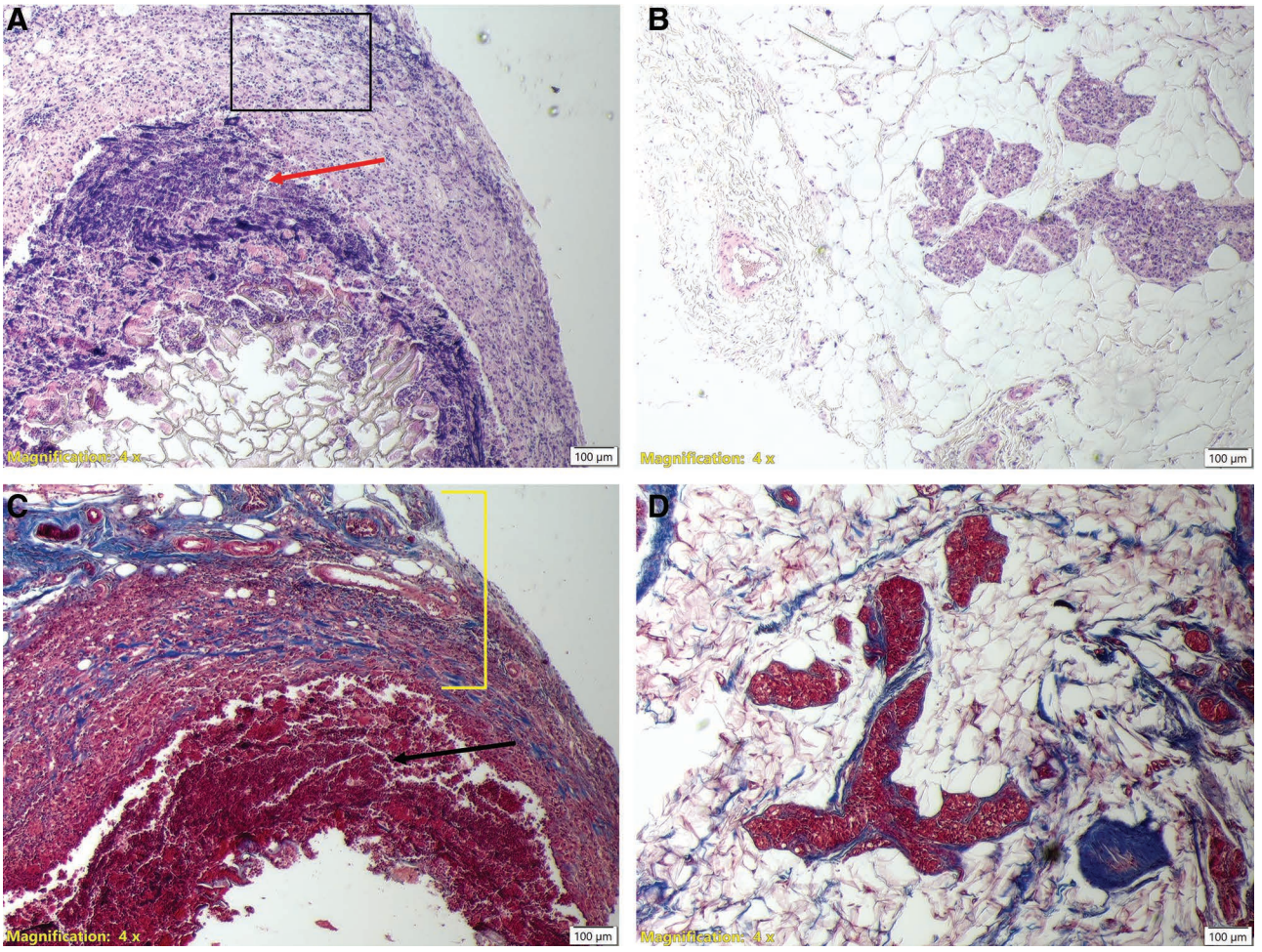

Fig. 7. Histological analysis of the needle capsule. Tissue extracted from the microsurgical needles was stained with hematoxylin and eosin (A & B) and Masson trichrome (C & D) and was imaged at 4× with a light microscope. Image A and C were centered around the tissue that was extracted from the microsurgical needles. Images B and D were normal tissue around the extracted tissue.

the lack of utility of radiographic imaging for localizing microsurgical needles, especially 9.0 needles commonly used in microsurgery.[2,9,13]

In addition to the significant difficulty locating microsurgical needles, hospital policies regarding procedures to locate them in the setting of an inaccurate count vary dramatically. At our institution, the current policy is for radiographic assessment intraoperatively for all lost needles regardless of size, and a dedicated attempt to locate the needle using magnetic sweepers and visual search. However, within other facilities in our geographic region, microsurgical needles are either not part of the count or can be disregarded if lost. This is of particular relevance given that the utility of needle recovery of any size is a point of dissent amongst surgeons.[35] Furthermore, as many other metallic objects of larger size, including vascular clips, are routinely left in patients without legal concern for disclosure, there is precedent for recognition of which retained objects represent potential harm to the patient. These discrepancies regarding policies for needle recovery further indicate the unclear risks of a retained microsurgical needle, adding to existing literature questioning the necessity of microsurgical needle recovery.

The additional time spent locating a lost microsurgical needle places patients at risk of further complications (ie, anesthesia, radiation, dissection) in addition to unnecessary healthcare expenditure. Previous studies have quantified this expense. For example, when accounting for the additional time spent in the operating room and the cost of a portable X-ray, a 4-year retrospective review of 153,263 coronary artery bypass graft procedures with a count discrepancy rate of 6.54% found that it would cost an additional $24 million per year to attempt to locate a missing needle.[7] Extrapolating our difficulty visualizing any of the 9-0 needles with dedicated imaging and the standardized area of needle placement, it would then be nearly impossible to extract the same microsurgical needles in human-size anatomy without any prior knowledge of its location.[2,9,13]

Our study has several limitations, including the use of a small animal model with semiquantitative methods of health evaluation, limited sample size, lack of blinding between experimental and control cohorts, and limited histological assessment without examining the nerve.

Despite these limitations, we believe this study offers evidence that microsurgical needle retention did not cause overt neurovascular insult manifesting as gross motor/behavioral deficits or pain indicated by inadequate weight gain, reduced grooming, or vocalizations.

Further studies should continue exploring the implications of retained microsurgical needles in larger cohorts, over longer periods, and potentially larger animal models. Furthermore, histology may be examined to further characterize the foreign body reaction and the distribution of inflammatory cells at various time points.

CONCLUSIONS

Locating a lost microsurgical needle adds additional operative time, further surgical intervention, radiation exposure, and increased hospital expenditure. In line with this assertion, imaging aided in the successful recovery of 8.0 needles, whereas 9.0 needles were unable to be visualized on fluoroscopy and were only recovered through lengthy and extensive dissection. Despite purposeful implantation of 8.0 and 9.0 needles orthogonal to the femoral vessels in rats, we found no difference in the overall health, IR-thermography, and structural integrity of neurovascular structures over 90 days of observation. Although our rat model may not perfectly mimic microsurgical needle retention in humans, our data suggest that microsurgical needle retention near neurovascular structures may be benign. Further investigation is needed to better understand the necessity of microsurgical needle recovery with the eventual goal of safely including microsurgical needles on the list of items that do not require radiographs or further dissection to locate.

Amber R. Leis, MD, FACS
Department of Plastic Surgery
University of California, Irvine
200 S. Manchester Ave, Suite 650
Orange, CA 92868
E-mail: leisa@hs.uci.edu

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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