**Title:** **Magnetization in Microsurgery: Causes & Potential Solutions**

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**Abstract:** Microsurgery is a surgical technique to connect blood vessels and nerves of approximately 1mm in diameter. During microsurgery, surgeons use operating microscopes to magnify the operative field and use needles with diameters as small as 0.10mm. The microscopic scale of the needle introduces unique challenges. For example, even a small amount of magnetization of the needle or surgical instrument can create a small magnetic force that interferes with the surgeon's ability to perform the operation. Over 50 members of the Canadian Society of Plastic Surgeons completed a national survey and it showed that on average, magnetization occurs in 38% of cases. The consequences of magnetization may include damage to the patient's blood vessels and/or nerves, sub-optimal post-operative recovery, and increased operating room time. We determined that magnetization occurs during microsurgery and identified the magnetic surgical mats and magnetic needle counters as sources of magnetization. Additionally, we propose and demonstrate two possible solutions to magnetization of microsurgical instruments and needles:

1. Thermal annealing treatment of either the surgical instruments or needles,
2. The use of a medical grade handheld demagnetizer in the operating room.

Thermal annealing treatment of manufactured instruments or needles will cause unwanted change in their material properties; hence this treatment has to be performed during the manufacturing process. The use of a medical grade handheld demagnetizer can readily be used during surgery in the operating room and is the recommended solution.

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# MAGNETIZATION IN MICROSURGERY: CAUSES & POTENTIAL SOLUTIONS

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## INTRODUCTION

The undesirable magnetization of surgical instruments is a common problem for practitioners of microsurgery. In this surgical subspecialty, the needles and anatomy are on the scale of tens of microns, and the surgeries are conducted almost entirely under a microscope, which requires considerable precision and dexterity.

At this mesoscopic scale, minor magnetic forces play a significant role, and can cause a surgeon's needle to behave unpredictably [1]. Magnetic interactions occur in over one-third of microsurgical cases, and lead to longer operation time, greater costs, and heightened task difficulty for the surgeons. The consequences of magnetization during microsurgery may include: increased damage to the blood vessels or nerves that are being sutured together, increased operating time, and fatigue for the surgeon and the OR staff.

The source of this magnetization is not commonly understood. In some cases the instruments arrive magnetized, while others describe the instruments becoming increasingly magnetic during a case. Generally, the current practice amongst microsurgeons is simply to cope with the added difficulty. However, if the magnetization becomes excessive, surgeons will sometimes request an entirely new set of instruments to complete the case.

The purpose of our work was twofold: (1) to determine the source of the magnetization in microsurgery; and (2) to conceive of and test potential solutions that could be reasonably applied in a clinical setting.

This paper describes our work in assessing the scope of the problem through a nation-wide survey of plastic surgeons; our exploration of potential causes of magnetization throughout the life-cycle of microsurgical instruments; and our investigation into potential solutions that can be employed in a clinical setting.

## THEORY

Most surgical instruments are manufactured from stainless steel. Stainless steel alloys are generally ferromagnetic because of their iron content. In the absence of a magnetic field, a ferromagnetic material's internal magnetic domains are randomly oriented, producing a net zero magnetic moment over the whole material. However, when exposed to an external magnetic field, these domains can become aligned and the material will experience a net magnetic force. In certain cases, the net-aligned internal structure of the ferromagnet can become locked in, even after the field has been removed, and the material will then produce its own magnetic field, enabling it to interact with other (non-magnetized) ferromagnetic materials.

In microsurgery, because of the small scale of the tools, even a minor amount of magnetization of the instruments can produce forces sufficient to move the needle, which makes it difficult for the surgeon to control.

To demagnetize a material, the internal magnetic structure must be randomized. There are a number of ways to accomplish this, two of which we will discuss here: heat-treatment and demagnetization.

*Heat Treatment*

Every ferromagnetic material has a characteristic temperature, known as the Curie temperature (Td), beyond which the internal magnetic domains are not fixed in any particular orientation. By heating a material above its Curie temperature, and then rapidly cooling it, it can lock the material into a non-magnetic state that resists subsequent magnetization. [2]

*Demagnetization*

By exposing a magnetized material to a strong, randomly oscillating external magnetic field, the internal magnetic domains can be scattered, which neutralizes the net magnetic property of the material. [2]

## METHODS

*National Survey*

To evaluate the frequency of magnetization and the associated frustration of surgeons, we sent a short multiple-choice survey to all members of the Canadian Society of Plastic Surgeons. The questions were as follows:

*1. How often do you find that magnetization occurs during microsurgery?*

- *a) Never happens*
- *b) in ~25% of cases*
- *c) in ~50% of cases*
- *d) in ~75% of cases*
- *e) in all cases.*

*2. When magnetization of instruments occurs, how much difficulty does it add to the operation?*

- *a) Becomes significantly easier*
- *b) Becomes slightly easier*
- *c) Stays at the same difficulty*
- *d) Becomes slightly more difficult*
- *e) Becomes significantly more difficult*

*Magnetization Cause Analysis*

We initially tested the effectiveness of the demagnetization process at the Medical Devices and Reprocessing Department (MDRD) at the Vancouver General Hospital (VGH) in Vancouver, Canada. This is a standard procedure that occurs before the sterilization of instruments. The experimental setup consisted of gentle touching and lifting of a surgical instrument against a 9-0 microsurgical needle (Ethicon, New Jersey, USA), which has a diameter of 0.10mm. The angle of deflection was measured as shown in Figure 1. A greater amount of magnetization corresponds to a greater deflection angle. Guided by the opinion of a plastic surgeon, we defined the instrument as functionally magnetized when the deflection angle was greater or equal to 60°. Below 60°, the magnetization was judged to not be sufficient to negatively affect the surgery.

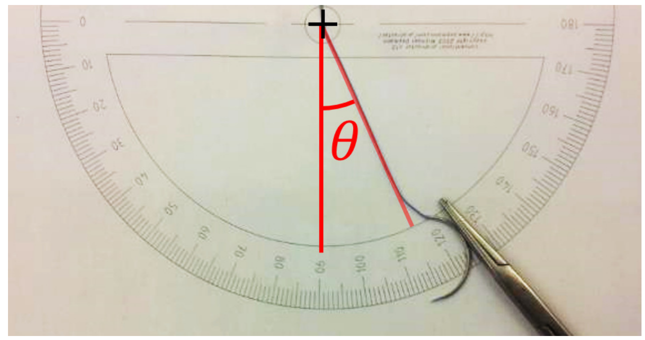

Figure 1: Instrument magnetization test. The needle deflection angle is measured from the vertical.

Next, we investigated the causes of magnetization during surgery. This included determining the occurrence of magnetization during extended use of the instruments, and assessing whether or not there was any magnetic transfer between (a) a magnetic needle counter box and the surgical needle, and (b) a magnetic surgical mat and a microsurgical driver instrument.

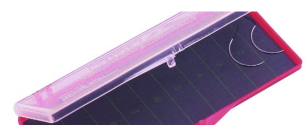

Figure 2: Magnetic needle counter box

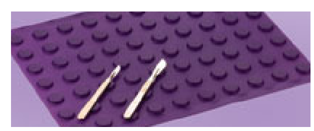

Figure 3: Magnetic surgical mat

Lastly, we observed six microsurgeries and tracked the occurrence of magnetization during the procedures. The locations of the microsurgery needles as well as the use of the magnetic mat and magnetic needle counter throughout the surgery were recorded as well.

*Magnetization Solution Analysis*

We identified and tested two possible solutions to the problem of magnetization in microsurgery: 1) treating the microsurgical needles with a rapid thermal annealing (RTA) furnace properties and 2) using a demagnetizer when magnetization occurs.

Using an RTA furnace, the microsurgical needles were heated to a temperature of 750°C, maintained there for 5 minutes, and then rapidly cooled (quenched). After the heat treatment, we tested the ability of the treated needle to resist magnetization as compared to the untreated needle.

For demagnetization, we selected the Neutrolator handheld demagnetizer (Electro-matic Products Co., Chicago, USA) because it is portable, medical grade, and easy to cover with a sterile drape. We set up a simulated operating room (OR) and worked with a surgeon to measure the effectiveness and ease of using the demagnetizer.

## RESULTS

*National Survey*

The national survey was sent out on August 8, 2013, and we received 56 replies. Figures 4 and 5 below show the results of the survey questions.

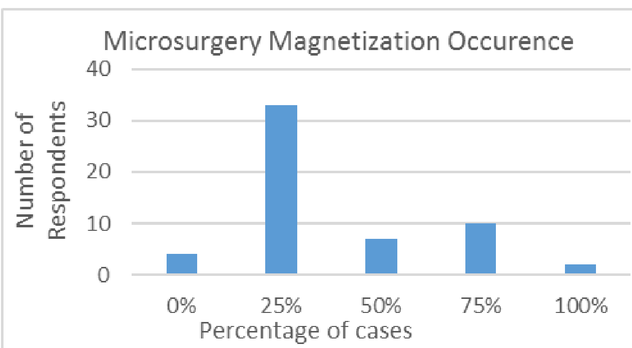


Figure 4: The mean of the survey response data suggests that magnetization occurs in 38% of cases.

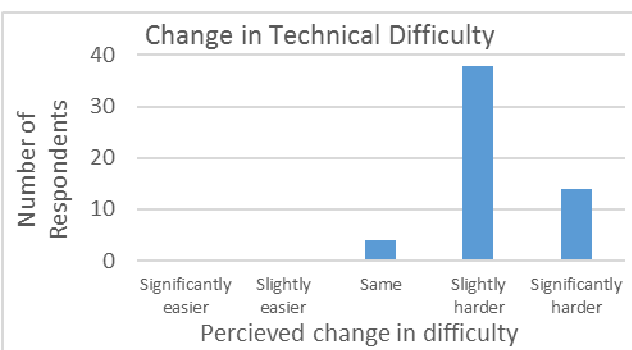


Figure 5: The survey responses indicate that surgeons find magnetization to increase the difficulty of microsurgery operations.

The results of the national survey show that magnetization occurs in approximately 38% of cases.

In the event of instrument magnetization, our respondents report that the operation is made slightly-to-significantly more difficult. No surgeon indicated that magnetization made the operation any easier, and only 7% of surgeons noted no change in difficulty.

*Magnetization Cause Analysis*

The degree of magnetization of every instrument in eight micro-surgical sets (for a total of 139 instruments) was tested.

Table 1: Summary of instrument magnetization deflection angle test results

| **Range of Deflection Angles** | | |
|---|---|---|
| 0°<θ<25° | 25°<θ<60° | 60°<θ |
| 17 | 5 | 0 |

From these results, we conclude that none of the tested instruments were functionally magnetized at the beginning of a procedure.

Further tests revealed that:

1. The active use of two demagnetized instruments over a five-minute period of time did not lead to any detectable magnetization of those instruments.

2. The microsurgical needle was magnetized when placed in a magnetic needle counter box.

3. The microsurgical instrument was *not* magnetized when it was placed in a magnetic needle counter box.

4. There was a transfer of magnetization from the magnetized needle to the instrument but not vice versa.

5. The magnetic surgical mat magnetized both the surgical instruments and needles.

No magnetization occurred during the six microsurgeries that were observed. The needles were not placed on the magnetic needle counter unless they were been discarded and the magnetic surgical mat was never used. All of the microsurgery cases observed were shorter than two hours.

*Magnetization Solution Analysis*

After the thermal treatment, it was found that the needle became more resistant to becoming magnetized. It was also observed that the needle's colour changed from a light, shiny silver to a dark, dull silver colour.

In the simulated OR test, the handheld demagnetizer was simple to use and effectively demagnetized the needles and instruments as determined by an expert surgeon and the deflection angle test (**Figure 1**). It was easy to keep it in a sterile condition using a sterilized drape. The surgeon felt that it could be used in a real OR.

## DISCUSSION

Magnetization in microsurgery is clearly an issue of national concern. Over 50 members of the Canadian Society of Plastic Surgeons completed a national survey and it showed that on average, magnetization occurs in 38% of the cases. This result is consistent with the anecdotal evidence that we heard from various plastic surgeons at VGH.

The magnetization cause analysis confirmed the expectation that the surgical instruments are functionally demagnetized before the surgeries.

The magnetization transfer tests suggest that, during microsurgeries, the surgical mats should not be used and microsurgical needles should not be placed in the magnetic needle counter box.

It was surprising that no magnetization occurred during the six microsurgeries that were observed, given the reported average rate of magnetization of 38% in the survey of the Canadian Society of Plastic Surgeons. The lack of magnetization during these surgeries is attributed to observer effect and short microsurgeries. The surgeons and nurses in the operating rooms were aware of the observation of the magnetic needle counters and magnetic mats. Several surgeons reported that magnetization is more likely to occur in longer microsurgeries. An alternative hypothesis is that the surgeons who responded to the survey overestimated the rate of magnetization due to an increase in frustration during microsurgical cases in which magnetization did occur.

In addition to the microsurgical practice guidelines listed above, we have concluded that the most feasible solution in the short-term is to use the handheld demagnetizer in the OR, as it can be adopted almost immediately by OR staff, whereas altering the thermal treatment of needles would require changes in their manufacturing process, which is beyond the control of the hospital.

## CONCLUSION

The cause of the frequent episodes of magnetization reported by the surgeons in our survey has not been fully determined. We have shown that instruments are likely fully demagnetized when surgery starts. The microsurgical needles are also likely initially not magnetized, although we did not specifically investigate this question. We therefore believe that most magnetization occurs during surgery and that bringing needles in contact with magnetic counter boxes or mats should be avoided. If magnetization does occur intraoperatively, a demagnetizing unit is practical to use to address the problem. In future, we plan to test the feasibility of using a handheld demagnetizer in the OR and to conduct a more in-depth survey on magnetization in microsurgeries to better identify the cause of magnetization.

## ACKNOWLEDGEMENTS

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