CIS II Spring 2020
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Seminar Critical Review
Tremor Reduction Assessment in Microlaryngeal Surgery

Selected Paper:
Akst, Lee M., et al. "Robotic Microlaryngeal Phonosurgery: Testing of a 'Steady-Hand' Microsurgery Platform." *The Laryngoscope*, vol. 128, no. 1, 2017, pp. 126–132., doi:10.1002/lary.26621.

Introduction:

The goal of my project is to perform user study to assess the degree of tremor reduction in robotic microlaryngeal surgical procedures on cadaveric phantoms. There are four main components in this project: experimental apparatus, user study, surgical tool tracking software, and data analysis (tremor reduction assessment). All of these are essential for my project to be successful, and I have found relevant papers for each of them. However, for this critical review I have chosen to review "Robotic Microlaryngeal Phonosurgery: Testing of a 'Steady-Hand' Microsurgery Platform". The reason for choosing this paper is that it is most relevant to the user study component of my project. Also, the robotic ear, nose, and throat microsurgery system (REMS), which is the robotic system used in this study, is the previous generation research system of the Galen robot, which is the robotic system I will be investigating in my project.

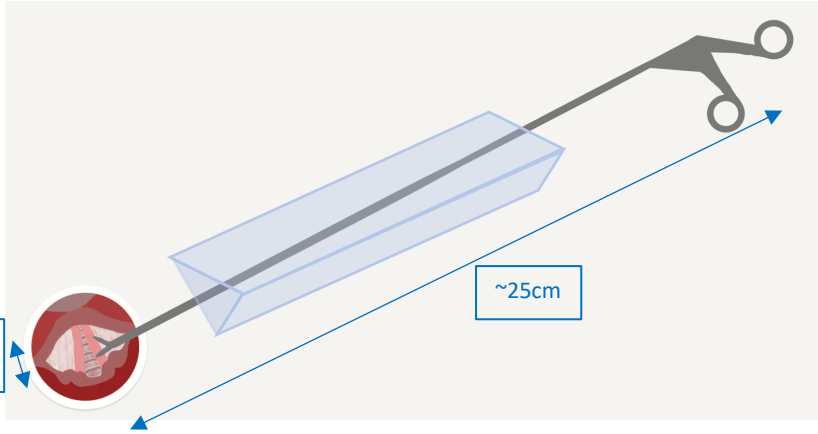
Summary of Problem:

Currently, robotic surgery is not being regularly translated into microlareangeal phonosurgical procedures. A novel robotic ear, nose, and throat microsurgery system (REMS) has been developed but further preclinical investigation of this "steady hand" microsurgery platform is necessary for evaluation of its surgical performance and usefulness.

Key Results and Significance:

The main result of this study is that the REMS improved the overall precision of simulated phonosurgery compared to manual performance. Objective improvement in surgical precision using the robotic system over manual surgery during a simulated phonosurgery task was seen. Also, participants reported the REMS as easy to use, felt their surgical performance improved using the REMS as compared to free-hand performance, and expressed a desire to use the robotic system in their clinical practice. The significance of these key results is that it provided further preclinical investigation of the novel robotic "steady hand" microsurgery platform, REMS.

Background:



Microlaryngeal phonosurgery are surgical procedures performed to better maintain, restore, or enhance the human voice. Imprecise surgery (i.e. with hand tremor) can lead to suboptimal voice outcomes. Current treatments that are available cannot effectively restore scarred vocal folds. Therefore, it is extremely important for surgeons to avoid scarring in the first place by performing surgery with the highest precision possible. However, as it can be seen in the diagram above, with instruments as long as 25cm going down the throat and laryngoscope to perform procedures on the vocal cords which are 1.25-1.7cm long for females and 1.75-2.5cm for males, it is difficult to maintain a completely steady hand. Thus, a novel robotic ear, nose, and throat microsurgery system (REMS) was developed, and its ability to improve surgical precision has been demonstrated in a preliminary study.

Experiment:

In this paper, simulated phonosurgery tasks were designed as follows, and the experimental setup is shown in the figure below. A 25cm laryngeal forceps were modified so that its tip held a 0.4-mm diameter needle, and participants were asked to move the needle through a spiral groove, starting from the center of the spiral to move outward without letting the needle touch the sides. To measure fail time, which is the time the needle contacted the spiral sides, an establishment of an electrical circuit was made. There were four different spiral targets used: 2.5mm spiral for a practice session, and 2mm, 1.5mm, and 1.2mm spirals. Nine participants (two laryngologists, two head and neck surgeons, one general otolaryngologist, one laryngology fellow, and three residents) volunteered for the study.

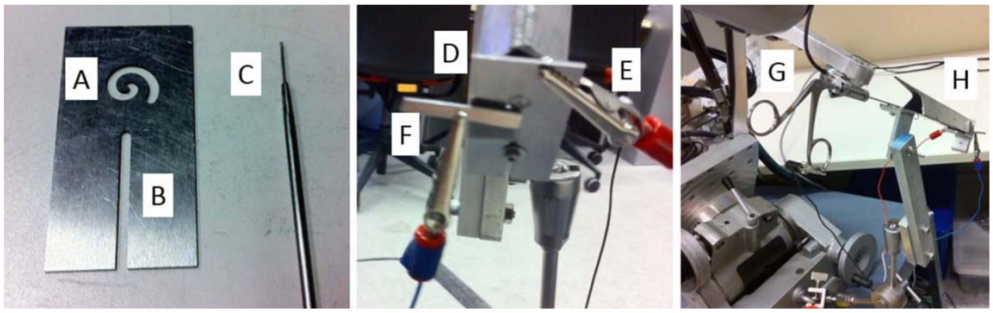


Fig. 2. The experimental setup. The spiral (A), mounting slot to allow positioning of the spiral at the end of the laryngoscope (B), and micro-laryngeal needle tip (C) are shown on the left. The middle image demonstrates a view of the spiral target (D) mounted at the end of a laryn-goscope with both failure electrode (E) and success electrode (F) attached. On the right, the REMS grasping arm (G) is used to hold the modified microlaryngeal needle within the laryngoscope (H). Edge of the 400-mm microscope can be seen in the upper left corner.

Data Collection:

After giving consent, the participants were given a practice session with the largest 2.5mm spiral to familiarize them with the robot and the surgical tasks. The participants were asked to move the instrument through the spiral groove as quickly as possible without touching its sides. Whenever the instrument made a contact with the sides, a buzzer rang to indicate the contact. Each participant performed five trials for each of the 2mm, 1.5mm, and 1.2mm spiral targets. The same trials for the same test conditions were performed for both with and without the REMS.

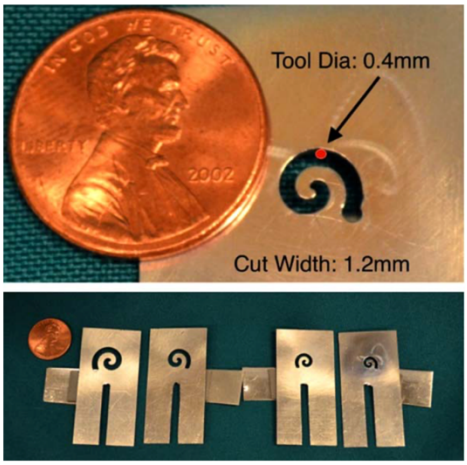


Fig. 3. The spirals, shown next to a penny. From left to right, the width of the spiral channels are 2.5 mm, 2.0 mm, 1.5 mm, and 1.2 mm, respectively. The 0.4-mm diameter of the microlaryngeal needle is represented by the red dot in the upper image.

Statistical Analysis:

The mean fail time was calculated over five trials with each combination of spiral size and robotic vs. manual performance. Paired analysis was performed, comparing the participants' fail times with the REMS to manual fail times. Statistical significance was assigned to results at a $P < .05$ level.

Descriptive Analysis:

For the descriptive analysis, participants were asked to provide feedback on the REMS using a survey form after experiment.

Results:

The following table shows the results of the fail times of all participants for each condition, and the corresponding P values. The results for all three spirals taken together and for each 2.0mm and 1.5mm test conditions, robotic performance was statistically more precise than manual performance. It is notable that for the most challenging test condition, 1.2mm, the difference between the two performances did not reach statistical significance. However, in a subgroup analysis, it was seen that the surgeons who were most familiar with microlaryngeal surgery showed statistically improved performance when using the robot. The 1.2mm condition remained challenging for the participants who were least familiar with microlaryngeal surgery.

TABLE II.
Fail Times Across All Participants for Each Condition.

	All Three Spirals	2.0 mm	1.5 mm	1.2 mm
Manual fail time	0.769 ± 0.568	0.549 ± 0.545	0.890 ± 0.518	0.868 ± 0.634
Robot fail time	0.284 ± 0.584	0.156 ± 0.226	0.075 ± 0.099	0.621 ± 0.923
P value	.003	.019	.002	.52

Data are presented in seconds as mean ± standard deviation with statistical comparison.

The following table shows the subjective feedback that the participants provided after the simulated phonosurgery experiment. Overall, the participants reported that their skill performance was higher with the robot compared to without the robot and believed the robot

would be beneficial if it were to be used in real surgeries. Also, all participants reported that they would desire to use the robot clinically once available.

TABLE III.
Subjective Feedback on Uses of the REMS Platform in Simulated Phonosurgery.

	Participant								
	1	2	3	4	5	6	7	8	9
Manual or robot first	M	R	M	R	M	R	M	R	M
Experience	6	6	4	2	3	6	3	7	7
Specialty	L	L	L	N/A	N/A	HN	N/A	HN	O
Left or right handed	Right	Right	Right	Right	Right	Right	Right	Right	Right
Used robot before	Y	Y	N	N	Y	Y	Y	Y	N
Experiment fair representation	4	5	4	3	5	5	3	3	3
Skill without robot	2	3	3	3	2	2	2	2	3
Skill with robot	5	5	5	4	5	5	3	4	4
Robot ease of use	5	5	4	3	5	4	3	4	4
Robot aid in real use	5	5	5	4	5	4	4	5	5
Better if bimanual?	Y	Y	Y	Y	Y	Y	Y	Y	Y
Would use it clinically?	Y	Y	Y	Y	Y	Y	Y	Y	Y

Experience is quantified by: 1 = medical student, 2 = junior resident, 3 = senior resident, 4 = fellow, 5 = attending <5 years, 6 = attending 6–10 years, 7 = attending >10 years. Subspecialty is quantified by: L = laryngology, HN = head and neck, O = other. Residents are marked N/A as they do not have a subspecialty yet. N = no; N/A = not applicable; M = manual; R = robot; REMS = robotic ear nose and throat microsurgery system; Y = yes.

Paper Assessment:

There are several strengths to this study. First, they used a novel approach to use simulated phonosurgery tasks for objective evaluation on improvement in surgical precision using REMS over manual surgery. Also, they conducted a crossover comparative study of surgical performance, which showed even in different levels of expertise, participants had improved precision when using REMS over unaided performance. Another strength is that they conducted a descriptive analysis of surgeon feedback, which provided necessary subjective feedback regarding the robotic system.

There are some improvements that can be made for this study as well. Despite the novelty of using simulated phonosurgery tasks for objective evaluation, only having experiments based on simulated phonosurgery tasks presents a limitation to this study. Further feasibility studies with actual phonosurgery tasks on cadaveric phantoms will be beneficial for the eventual clinical use of this kind of “steady-hand” robotic system. Also, such simulation provided some objective evaluation on the improvement of surgical precision when using this robotic system, however the evaluation was not dependent on direct measurements of tremor. In future studies, objective assessment of the tremor reduction itself will be necessary for further proof of the usefulness of REMS.

Relevance:

This paper is applicable to my project because first, the robotic ear, nose, and throat microsurgery system (REMS), which is the robotic system used in this study, is the previous generation research system of the Galen robot, which is the robotic system I will be using in my project. It is also the study that I will be building upon in my project. In my project, I will be conducting user study with microlaryngeal surgery tasks on cadaveric phantoms and will be using vision-based surgical tool tracking for a more direct tremor reduction assessment, which are the key points to be addressed in a further study for the Galen robot.

Conclusion:

In conclusion, this paper was a great resource for my project. It explains the motivation, experimental setup, comparative study of surgical performance, and descriptive analysis of surgeon feedback. I will continue to refer to this paper in the future (especially when writing academic paper with surgeons).

Reference:

Akst, Lee M., et al. “Robotic Microlaryngeal Phonosurgery: Testing of a ‘Steady-Hand’ Microsurgery Platform.” *The Laryngoscope*, vol. 128, no. 1, 2017, pp. 126–132., doi:10.1002/lary.26621.