

ANNUAL REPORT 2018

# Surgical Hearing Implant Program

Otolaryngology - Head & Neck Surgery



© December 2018  
SHIP Annual Report  
Health Sciences Centre  
Shared Health Services  
Manitoba Health, Seniors and Active Living

COCHLEAR IMPLANT RECIPIENTS CELEBRATE MANITOBA'S 250<sup>TH</sup> IMPLANT PROCEDURE

# Annual Report

Surgical Hearing Implant Program

2018

REPORT HIGHLIGHTS

## Message from the Director

by Dr. Jordan Hochman – Medical Director

2018 has been an exceptional year for the Surgical Hearing Implant Program.

The Universal Newborn Hearing Program has made a significant impact on the age of pediatric implantation. Under the leadership of Dr. Darren Leitao, the average age of implantation has decreased dramatically to near 12 months. This will have remarkable impact on the ease and speed of language acquisition in these children. We recognized this milestone with the media.

The Children's Hospital Research Foundation sponsored the event and raised capital for much needed diagnostic equipment.

Our research in surgical simulation and the ethics of implantation continues to evolve. The work has been recognized with a large Federal grant as well as publications and presentations in North America and Europe.



In September we held a Barbeque to celebrate our 250th Cochlear Implant. This was an opportunity to get together as a community and

reunite patients with the incredible teams of staff from the Central Speech and Hearing Clinic and Health Sciences Centre. It was a very humbling event.

I look forward to the challenges of expanding indications for cochlear implantation and am excited to continue collaborating with our many partners in care.

Jordan Hochman MD  
Medical Director  
December 2018



### Cochlear Implant Summary

A detailed description of cochlear implant surgical production for 2017, including information on program finances, changes in wait times and the current adult waiting list.

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### Bone Anchored Implant Summary

A detailed description of bone anchored implant surgical production for 2017, including information on program finances, changes in wait times and the current adult waiting list.

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# Program Personnel

- Jordan Hochman MD – Director and Adult Cochlear Implant Surgeon
- Darren Leitao MD – Pediatric Cochlear Implant Surgeon
- Les Garber MD – Bone Anchored Implant Surgeon.
- Justyn Pisa AuD – Program Coordinator
- Pam Campbell – Executive Director, Central Speech & Hearing Clinic
- Kristy Mackie MSc – Audiologist
- Daniela Stangherlin AuD – Audiologist
- Jacob Sulkers MSc – Audiologist
- Kelly Boyd – Office Manager



## JUSTYN PISA – PROGRAM COORDINATOR

Justyn Pisa is an implant audiologist and has been the coordinator of SHIP since the program was initiated in 2011.

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# Coordinator Program Summary

by Justyn Pisa AuD

The following report will outline the current status of the Surgical Hearing Implant Program (SHIP) of the Department of Otolaryngology – Head & Neck Surgery at Health Sciences Centre (HSC) as of December 31, 2018.

2018 represented an exciting year for SHIP amidst the changing landscape of health care delivery in Manitoba. Despite staffing changes and funding adjustments, SHIP met productivity quotas for both cochlear implant and bone anchored implants. This resulted in decreased adult wait times to within national norms for both implant programs.

2018 also marked a milestone for SHIP in reaching our 250th implant for the Province. SHIP held an afternoon event for approximately 300 cochlear implant recipients and their families to celebrate this achievement.

The event was well received and allowed this small, but growing community to meet and share experiences (see pages 6,7).

Since 2016, SHIP has received a total of 5 pediatric referrals for cochlear implantation from the Universal Newborn Hearing Screening (UNHS) program. All 5 pediatric patients have been implanted under the age of 1 year and have successfully incorporated the technology into their ongoing speech and language development. SHIP considers these patients as the "next generation" of cochlear implant users who represent the best opportunity to eliminate speech and language delays in pre-lingually implanted patients.

We are proud to be involved in these ground breaking initiatives and will continue to maintain our program as a Centre of Excellence in Canada.

## CI Sound Processor Upgrades

In 2018, a total of 6 pediatric patients were granted 8 cochlear implant sound processor upgrades through the provincial cochlear implant replacement program. This program provides 80% of the cost towards processor upgrades for pediatric recipients every 5 years. Since 2013, the program has processed 42 applications for a total of 62 sound processors.

## Newborn Hearing Screening

Since 2016, the WRHA's universal newborn hearing screening program has identified a total of 7 candidates for cochlear implantation with an average of just over 3 infants per year. To date, 4 of these infants have been implanted bilaterally under 12 months of age, representing a significant decrease in the average age of implantation for pre-lingually deafened recipients. We look forward to charting the progress of these new CI recipients.

## Revision Surgeries

SHIP continues to perform 1-2 revision surgeries per year for the CI program and 3-4 revision surgeries for the BAI program each year. In 2018, the CI program re-implanted one individual for a failed internal electrode under manufacturer warranty. The BAI program provided longer abutments for 3 individuals to alleviate chronic skin growth and infection issues.

## Future Outlook

SHIP will continue to monitor the number of infants identified through the UNHS program as well as the number of revision surgeries required in order to generate accurate forecasts for future production and funding allocations. In this way, we can ensure the adult waiting list is not extended and adult wait times remain consistent with implant centres across Canada. We will present our data at the national implant conference in April 2019.

# Cochlear Implant Summary

by Justyn Pisa AuD



The Cochlear Implant (CI) Program completed 32 surgeries in 2018. These included 26 unilateral procedures and 6 bilateral procedures on 24 adult patients and 8 pediatric patients. Since the start of the program, SHIP has implanted a total of 270 cochlear implants on 245 individual patients.

## Wait Times

There are currently 12 patients awaiting trial for audiological candidacy assessment and 34 patients awaiting cochlear implant surgery.

The cochlear implant program continues to generate an average of approximately 3 (2.8) new surgical candidates per month.

The current surgical wait time was approximately 16.3 months for cochlear implant surgery in 2018. This represented a decrease of 2.6 months from the previous year, largely due to a few expedited cases. The average wait time is expected to return to approximately 18.5 months by the end of the 2019 fiscal year, putting SHIP behind the national implant centre norms.

## Unique Implant Case

One of our expedited cases this year involved an adult patient with sudden sensorineural hearing loss as a result of bacterial meningitis. This patient felt somewhat ill before retiring, only to wake up several hours later without any remaining hearing or vision bilaterally. Given the unexpected outcome and severe difficulty communicating, the patient remained hospitalized for several months, without much understanding of what had transpired.

Meningitis presents a small window of time in which cochlear implantation can achieve positive outcomes. Through a collaborative effort among health care

providers from multiple disciplines and hospitals, bilateral cochlear implantation was performed exactly 85 days post-infection. During the activation of both implants, immediate benefit was observed as this patient was able to converse freely with her family, after many weeks of complete silence. We are happy to report this patient now scores in the 90<sup>th</sup> percentile for speech understanding as the implants have restored full communicative ability.

## Increasing Patient Demand

Demand for bilateral implantation in adults continues to grow from our community of current recipients. SHIP has allocated funding for 2 sequential bilateral cases each year in order to address this patient driven effort. Subjective reports from recipients are extremely positive as they regain the use of both ears for better speech understanding, localization and hearing in noise.

Further, there is growing evidence to suggest that patients with unilateral sensorineural hearing loss ("Single-Sided Deafness") can benefit from cochlear implantation. While implantation for unilateral hearing loss is not currently a standard of care across the country, we expect candidacy criteria will expand to include this patient population in the near future.

Finally, revision surgery volumes have remained at the previous level of 2 each year. We forecast this trend will continue to grow and remain committed to supporting these patients.

## Future Outlook

Patient demand and technological advancement will continue to drive hearing health care. SHIP will continue to adapt to the changing health care landscape to provide the best possible care to patients.

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## 2018 CI Production

The surgical hearing implant program utilized 38 cochlear implant products on 32 individual patients in the 2018 calendar year. This represents a 20% (10 units) decline in surgical output from 2017.

# 16.3 mos

## 2018 Average Adult Wait Time

The average adult wait time in 2017 was 16.3 months (+/- 4.3 months). This represents an average decrease in wait times by 2.6 months which is relatively in-line with national norms across Canadian implant centres.

# 34

## Current Adult Waiting List

The current adult wait list comprises 34 patients. SHIP cleared an average of 2.83 new cochlear implant candidates per month in 2018, with a projected wait list of 43 patients by the start of the next fiscal year in 2019.

# Bone Anchored Implant Summary

by Justyn Pisa AuD



The Bone Anchored Implant (BAI) Program completed 11 surgeries in 2018. These 11 unilateral procedures included 10 adult patients and 1 pediatric patient. Since the start of the program, SHIP has implanted a total of 108 bone anchored implants on 107 individual patients.

## Wait Times

There are currently 6 patients awaiting trial for audiological candidacy assessment and 14 patients awaiting bone anchored implant surgery.

The bone anchored implant program generated an average of 1.2 new surgical candidates per month, a decrease from previous years due to limitations placed on candidacy criteria.

The current surgical wait time is 13.7 months for bone anchored implant surgery, representing an average decrease of 2.0 months from the previous year. After initial incremental increases in the adult wait list and wait times for Baha surgery, the program has demonstrated some degree of stability over the past year which we hope will continue into the future.

## Increased Costs

The number of revision surgeries required each year continues to grow as our patient population expands and new treatment options become available. The availability of abutment extensions has altered typical treatment for chronic wound management issues with the bone anchored implant.

The longer abutments are seen by both the surgical team and patients as a preferable treatment option to tissue reduction for chronic skin growth and infection around the abutment. As a result, surgical costs have increased to accommodate the need for abutment replacement in these cases. Despite the fact that these cases comprise less than

10% of all bone anchored implant recipients, it does represent a significant impact on the SHIP annual budget.

## Funding

Despite the number of revision surgeries in 2018, SHIP is still within its device budget allocation for BAI procedures. However, as we continue to support more patients each year, the costs of maintaining the internal and external equipment are projected to grow.

## Unique Implant Case

One of our pediatric BAI recipients with bilateral conductive hearing loss has demonstrated significant improvement in school since being implanted unilaterally at age 5. Due to his age and success with one implant, SHIP agreed to implant the contralateral ear with an additional BAI. As one of very few bilateral BAI recipients in North America, this patient participated in a research project at Arizona State University and has reported increased benefit in his personal and academic life.

## Collaborative Research

SHIP remains partnered with the University of Alberta and the University of Western Ontario on a project designed to validate a new skull simulator for verifying patient activations. The skull simulator mimics the sound energy present within the skull as amplification is applied through mechanical vibration. As the simulator is connected to a real-ear verification system, a graphical display of sound pressure will be visualized at each frequency.

Ultimately, the goal of the skull simulator is to provide implant audiologists with a tool to verify the accuracy of their fittings and increase end benefit to patients.

# 11

## 2018 BAI Production

The surgical hearing implant program utilized 11 bone anchored implant products on 11 individual patients in the 2018 calendar year. This production is consistent with previous years since the program's inception.

# 13.7 mos

## 2018 Average Adult Wait Time

The average adult wait time in 2018 was 13.7 months (+/- 9.6 months). This represents an decrease in the average wait time by 2 months compared to 2017 and represents a positive change in wait times since the program's inception.

# 14

## Current Adult Waiting List

The current adult wait list comprises 14 patients. SHIP cleared an average of 1.2 new bone anchored implant candidates per month in 2018 with a projected wait list of 20 patients by the start of the next fiscal year in 2019.

# Patient Spotlight: 250<sup>th</sup> CI Celebration

by Justyn Pisa AuD, Implant Coordinator



## 250<sup>th</sup> CI Celebration

After 7 full years in operation, SHIP reached 250<sup>th</sup> implants in July of 2018. Fittingly, the 249<sup>th</sup> and 250<sup>th</sup> cochlear implants were used for a 10-month old infant, identified through the Universal Newborn Hearing Screening program.

The celebration was months in the making and was held on a warm and sunny Sunday afternoon in September at the Waverly Community Centre.

Approximately 300 cochlear implant recipients and their families attended the event, which included a hot dog lunch, games and activities for kids, a giant bouncy castle, and a short program by SHIP's team of surgeons, audiologists and auditory-verbal therapists.



## Tremendous Support

SHIP would like to acknowledge industry support for this event, which allowed us to provide an afternoon of fun and games but also an opportunity for our implant patients and their families to meet and foster a sense of community among recipients across Manitoba. Specifically, we would like to thank Advanced Bionics, Cochlear Canada, Med-El, and Oticon Medical.

## Video Testimonials to Come

SHIP employed both a professional photographer and videographer for this event to capture spontaneous moments throughout the day, but also to record the impact these implant devices have on the everyday lives of our recipients.



SHIP will release a series of testimonial videos in the coming months on our department website and several social media platforms once they are ready.

## SHIP Team Members

The success of SHIP comes from the hard work and dedication of its team members. From diagnosis to surgery to rehabilitation, our team is honoured to serve Manitobans of all ages.



# Clinician's Corner: Central Speech & Hearing Clinic

by Kristy Mackie, MSc, Implant Audiologist

## CI Centre Update

There is always something new and exciting when working with cochlear implants and this year has been no different. 2018 saw the youngest child ever implanted in Manitoba thanks to the Universal Newborn Hearing Screening program.



We also began working with a fourth cochlear implant company: Oticon Medical. The audiologists have to keep on their toes while we learn to assess and monitor younger children, and keep up with new technology..

## New Testing Equipment

This year we were fortunate to be the recipients of a new audiometer and tympanometer that allow us to assess and monitor our cochlear implant candidates and recipients. They were graciously donated to us as part of a fundraising campaign through the Children's Hospital Foundation. The new equipment replaces the old, obsolete pieces that treated us well and will allow us to be more efficient and confident in our work.



## Improving the Lives of CI Users

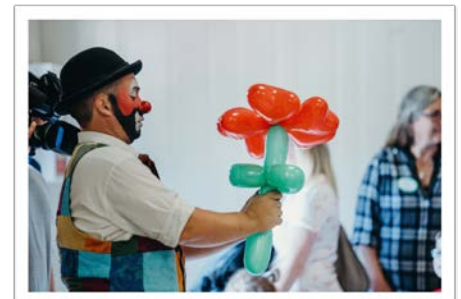
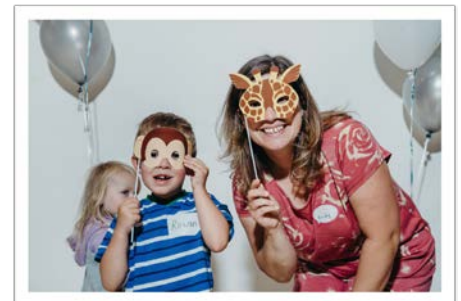
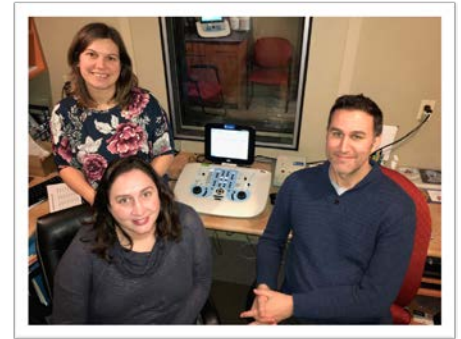
As implant Audiologists, we are fortunate to be able to follow patients beyond the surgery and mark major hearing milestones with them and their families. We love to hear about the first time a child began making the actions for Itsy Bitsy Spider the minute they started to hear it. We are ecstatic to listen to an adult describe hearing the first phone call they make to a loved one.



Progress can be slower for some people but even the smallest things can make a big difference. When people are given the right tools and the right support, they can achieve things that were once thought to be impossible.

## Continuing Education

In February, the audiologists traveled to Advanced Bionics headquarters in Valencia, California to learn about product development. There was even time to try building our own cochlear implant electrode array. It was evident that these engineers, scientists and clinicians are experts in their field and are dedicated to the continued excellence of their product offerings.





# SHIP Research Production

by Justyn Pisa AuD



## Podium/Poster Presentations

Hochman J., Unger B., Kraut J., Hombach-Klonish S. **Gesture-Controlled Three Dimensional Anatomy: A Novel Teaching Tool in Head and Neck Surgery.** American Academy of Otolaryngology Annual Meeting. Washington DC. September 2012.

Kraut J, Hochman JB, and Unger B. 2013. **Temporal bone surgical simulation employing a multicore architecture.** Proceedings of 2013 26th Annual IEEE Canadian Conference on Electrical and Computer Engineering (CCECE – Regina, SK) pp. 1–6.

Wong D, Hochman J, Unger B, Kraut J. **Face and Content Validation of a Rapid Prototyped Temporal Bone Model.** Presented at the 2013 Annual Canadian Society of Otolaryngology - Head & Neck Surgery Meeting, June 2-4. Banff, AB.

Wong D, Hochman J, Unger B, Kraut J. **Soft Tissue Modeling in Temporal Bone Simulation.** Presented at the 2013 Annual Canadian Society of Otolaryngology - Head & Neck Surgery Meeting, June 2-4. Banff, AB.

Wong D, Hochman J, Unger B, Kraut J. **Controlled Interactive Three Dimensional Anatomy: A Novel Teaching Tool in Head and Neck Surgery.** Presented at the 2013 Annual Canadian Society of Otolaryngology - Head & Neck Surgery Meeting, June 2-4. Banff, AB.

Le T., Leitao D., Hochman J. **Hair Barrette Induced Cochlear Implant Receiver Stimulator Site Infection with Extrusion.** Canadian Society of Otolaryngology, Banff AB, June 2013.

Kraut J., Unger B., Hochman J. **Temporal Bone Surgical Simulation Employing A Multicore Architecture.** Canadian Conference on Electrical and Computer Engineering, Regina SK, June 2013.

Unger B, Kraut J, Hochman JB. **A Novel Rapid Prototyped Temporal Bone Model for Surgical Dissection.** American Academy of Otolaryngology Annual Meeting. Vancouver BC. Sept. 2013.

Unger B., Kraut J., Hochman J. **Comparison of Isomorphic 3D Printed and Virtual Haptic Temporal Bone Simulation in Education.** Simulation Summit, RCPSC, Vancouver BC, Nov. 2013.

Wong D., Kraut J., Unger B., Hochman JB. **Comparison of Isomorphic 3D printed and Virtual Haptic Temporal Bone Simulation.** Canadian Society of Otolaryngology (CSO), Ottawa ON, May 2014.

Wong D, Unger B, Kraut J, Hochman J. **Comparison of Cadaveric and Isomorphic Virtual Haptic Simulation in Temporal Bone Education.** Presented at the 2014 Annual Canadian Society of Otolaryngology - Head & Neck Surgery Meeting, May 11-13. Ottawa, ON.

Bertram J. Unger, Kraut J, Hochman J. **Design and Validation of 3D Printed Complex Models with Internal Anatomic Fidelity for Training and Rehearsal.** Medicine Meets Virtual Reality. Manhattan Beach CA. Feb 2014.

Hochman J, Rampersad V, Sepehri N, Kraut J, Pisa J, Unger B. **Import of Haptic Manipulandum & Device Fidelity on Expert User Perception in Virtual Temporal Bone Surgery.** Presented at 2015 Annual Combined Otolaryngology Spring Meetings (COSM) April 22-25; Boston, MA.

Hochman J., Kraut J., Pisa J., Rhodes C., Unger B. **Comparison of Anatomically Matched 3D Printed and Virtual Haptic Temporal Bone Simulation.** Combined Otolaryngology Spring Meeting COSM, May 2014, Las Vegas, NV.

Hochman J, Tordon B, Unger B, Pisa J. **Importance of Stereoscopy in Haptic Simulation for Temporal Bone Surgical Training.** Presented at the 2015 Annual Canadian Society of Otolaryngology - Head & Neck Surgery Meeting, June 6-9. Winnipeg, MB.

Hochman J, Rampersad V, Sepehri N, Unger B, Pisa J. **Import of Haptic Manipulandum and Device Fidelity on Expert User Perception in Virtual Temporal Bone Surgery.** Presented at the 2015 Annual Canadian Society of Otolaryngology - Head & Neck Surgery Meeting, June 6-9. Winnipeg, MB.

Moore P., Hochman J., Blakley B. **Vestibular Hypofunction as an Indicator of Lateral Skullbase Pathology.** Canadian Society of Otolaryngology (CSO), Winnipeg Canada, June 2015.

Pisa J, Sulkers J, Butler J, West M, Hochman J. **Impact of Stereotactic Radiosurgery on Cochlear Implant Performance in Patients with Neurofibromatosis Type II.** Presented at the 2016 Annual American Cochlear Implant Alliance Conference. May 11-14, Toronto, ON.

Hochman J, Unger B, Pisa J, Fliker A. **Mixed Reality Simulation.** Presented at 2017 Annual AAO – HNSF Meeting & OTO Experience. September. Chicago, IL.

Kazmerik K, Unger B, Pisa J, Hochman J. **Evaluation of Trainee Drill Motion Patterns during Temporal Bone Simulation with 3D Printed Models.** Presented at 2017 Annual Combined Otolaryngology Spring Meetings (COSM) April 26-30; San Diego, CA.

Unger, B. Tordon, B., Pisa J., Hochman J. **Importance of Stereoscopy in Haptic Training of Novice Temporal Bone Surgery.** Medicine Meets Virtual Reality. Los Angeles CA, April 2016.

Kazmerik K, Pisa J, Gentile L, Unger B, Hochman J. **Comparison of Drill Technique; Cadaveric and Printed Temporal Bone.** Presented at 2017 Annual Combined Otolaryngology Spring Meetings (COSM) April 26-30; San Diego, CA.

Gousseau M, Unger B, Pisa J, Mowat S, Westerberg B, Hochman J. **Validation of Novel Temporal Bone Dissection Scale.** Presented at 2017 Annual Combined Otolaryngology Spring Meetings (COSM) April 26-30; San Diego, CA.

Sulkers J, Mackie K., Stangherlin D., Pisa J., Hochman J. **Cochlear Implant Benefit by Age: Comparing Speech Perception Outcomes in Adults Implanted Prior to and After Seventy.** ACI International Cochlear Implant Conference, Toronto ON, May 2016.

Hochman J., Pisa J., Rampersad V., Unger B., Sepehri N. **The Effect of Haptic Force Resolution in Virtual Temporal Bone Surgery.** American Academy of Otolaryngology Annual Meeting. San Diego. Sept. 2016.

Kazmerik K, Pisa J, Gentile L, Unger B, Hochman J. **Printed Bone Hand Motion Analysis.** Presented at 2017 Annual National Medical Students Research Forum. April. Galveston, TX.

Dolatbadi A.D., Hochman J., Mousavi Z., Unger B. **Automated Assessment of Temporal Bone Surgical Simulation Employing an Improved Model of Bone-Drilling Force Feed Back.** EuroHaptics. Pisa Italy. May 2018.

Wong V., Pisa J., Unger B., Hochman J. **Construct Validation of a Printed Bone Substitute in Otolologic Education.** Canadian Society of Otolaryngology Meeting, Quebec City Quebec. June 2018.

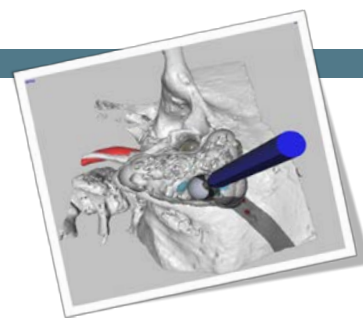
Gigiotti D., Blakley B., Moore P., Hochman J. **MRI is not Indicated in the Management of Isolated Vestibular Weakness.** Canadian Society of Otolaryngology Meeting, Quebec City Quebec. June 2018.

Wong V., Pisa J., Unger B., Hochman J. **Appraisal of a Printed Bone Substitute.** American Academy of Otolaryngology Annual Meeting. Atlanta. Sept. 2018.

Pisa J. **Hearing Health Care: An Investment in the Future.** Presented for the Faculty of Medicine, University of Manitoba. Winnipeg, Manitoba. October, 2018.

# SHIP Research Production

by Justyn Pisa AuD



## Peer-Reviewed Publications

Forzley B, Chen J, Nedzelski J, Lin V, Shipp D, Godlovitch G, Hebert P, Hochman J. **Considerations of Candidacy for Bilateral Cochlear Single Payer Universal Health Care System.** *Laryngoscope.* 2013 Dec;123(12):3137-40.

Kraut J., Unger B., Hochman J. **Temporal Bone Surgical Simulation Employing A Multicore Architecture.** *Electrical and Computer Engineering, 2013 26th Annual IEEE Conference.* 10.1109/CCECE.2013.6567771, Page1-6.

Unger B., Kraut J., Hochman JB. **Method and System For Rapid Prototyping Of Complex Structures.** United States Patent and Trademark Office Publication No.US-2014-0031967-A1, Publication Date:01/30/2014.

Unger BJ, Kraut J, Rhodes C, Hochman J. **Design and Validation of 3D Printed Complex Bone Models with Internal Anatomic Fidelity for Surgical Training and Rehearsal.** *Stud Health Technol Inform.* 2014;196:439-45.

Hochman JB, Kraut J, Kazmerik K, Unger BJ. **Mixed reality temporal bone surgical dissector: mechanical design.** *Otolaryngol Head Neck Surg.* 2014 Mar;150(3):448-54.

Wong D, Unger B, Kraut J, Pisa J, Rhodes C, Hochman JB. **Comparison of cadaveric and isomorphic virtual haptic simulation in temporal bone training.** *J Otolaryngol Head Neck Surg.* 2014 Oct 13;43:31.

Hochman JB, Sepehri N, Rampersad V, Kraut J, Khazraee M, Pisa J, Unger B. **Mixed reality temporal bone surgical dissector: mechanical design.** *J. Otolaryngol. - Head Neck Surg. J.* 2014;43:20-23.

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Hochman JB, Unger B, Kraut J, Pisa J, Hombach-Klonisch S. **Gesture-controlled interactive three dimensional anatomy: a novel teaching tool in head and neck surgery.** *J Otolaryngol Head Neck Surg.* 2014;Oct 7;43:38.

Le T., Leitao D., Hochman JB. **Hair Barrette Induced Cochlear Implant Receiver Stimulator Site Infection with Extrusion Case.** *Rep Otolaryngol.* 2015; 51074.

Hochman JB, Rhodes C, Kraut J, Pisa J, Unger B. **End User Comparison of Anatomically Matched 3-Dimensional Printed and Virtual Haptic Temporal Bone Simulation: A Pilot Study.** *Otolaryngol-Head Neck Surg.* 2015;153:263-268.

Szturm T., Reimer K., Hochman J. **Home-Based Computer Gaming in Vestibular Rehabilitation of Gaze and Balance Impairment.** *Games for Health J.* 2015 Jun;4(3):211-20.

Hochman JB, Rhodes C, Kraut J, Pisa J, Unger B. **Design and Validation of 3D Printed Complex Bone Models with Internal Anatomic Fidelity for Surgical Training and Rehearsal.** *Otolaryngol Head Neck Surg.* 2015;Aug;153(2):263-8.

Szturm T1, Hochman J, Wu C, Lisa L, Reimer K, Wonneck B, Giacobbo A. **Games and Telerehabilitation for Balance Impairments and Gaze Dysfunction: Protocol of a Randomized Controlled Trial.** *JMIR Res Protoc.* 2015 Oct 21;4(4):e118.

Hochman JB, Rhodes C, Wong D, Kraut J, Pisa J, Unger B. **Comparison of cadaveric and isomorphic three-dimensional printed models in temporal bone education.** *Laryngoscope.* 2015 Oct;125(10):2353-7.

Unger B., Torodon B., Pisa J., Hochman J. **Importance of Stereoscopy in Haptic Training of Novice Temporal Bone Surgery.** *Stud Health Technol Inform.* 2016;220:439-45.

Pisa J, Sulkers J, Butler J, West M, Hochman J. **Stereotactic Radiosurgery does not appear to Impact Cochlear Implant Performance in Patients with Neurofibromatosis Type II.** *Journal of Radiosurgery & SBRT.* 2017. July.

Unger B, Sepehri N, Rampersad V, Pisa J, Gousseau M, Hochman J. **Elements of Virtual Temporal Bone Surgery: Manipulandum Format may be More Important to Surgeons than Haptic Device Force Capabilities.** *Laryngoscope Investig Otolaryngol.* 2017. Oct 2:29.

Pisa J, Gousseau M, Mowat S, Westerberg B, Unger B, Hochman JB. **Simplified Summative Temporal Bone Dissection Scale Demonstrates Equivalence to Existing Measures.** *Ann Otol Rhinol Laryngol.* 2017 Nov 1:348.

Hochman JB, Pisa J, and Cham, B. **Prioritization of Re-implantation in Previously Successful Cochlear Implantation Following Natural Device Failure.** *Otology & Neurotology,* 2018, Vol.39(8), p.651-653.

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