Determining Parathyroid Vascularity in a Clinical Setting

Vanderbilt University

Department of Biomedical Engineering

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Itamar Shapira
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Yu Zhou

Abstract

Endocrine surgeons at the Vanderbilt University Medical Center have requested a device that will aid in the identification of perfused parathyroid tissue over poorly perfused parathyroid tissue. If a parathyroid gland's perfusion source is damaged during surgical operation, it may become unperfused and lose parathyroid function, specifically bodily calcium homeostasis; moreover, in such a situation the parathyroid is minced and reimplanted in the sternocleidomastoid muscle. Consequently, physicians have a need for quantification of the perfusion of parathyroid gland. To address this clinical need, a team of senior undergraduate

biomedical engineering students will design and build a device to quantify the perfusion of parathyroid tissue in order to replace the subjective visual method currently employed. The team members are Gabrielle Caires de Jesus, Tianhang Lu, Itamar Shapira, James Tatum, and Yu Zhou. The advisors for this project are Dr. Matthew Walker III, Dr. Anita Mahadevan-Jansen, and PhD student Melanie McWade. The overall objectives for this project are as follows:

- Consider and assess several imaging techniques to determine parathyroid tissue perfusion and to select an optimal technique for use in a clinically useful device.
- Implement optimal imaging technique in a sterilizable, clinically safe, and rapidly analyzing device adapted to use by surgeons *in situ*. Ideal implementation of the technique will result in a modular device easily integrated into the existing fluoroscopy instrumentation.
- Establishing proof of concept (POC) with *ex vivo* animal testing and preliminary clinical trials and creating documentation to encourage further licensure agreement with Anasys Instruments.

The success of the project will be based off our device's ability to determine parathyroid perfusion in a clinical setting.

Introduction

Problem Statement:

Endocrine surgery often requires thyroidectomy or parathyroidectomy. Following total or incomplete thyroidectomy, parathyroid tissues are often exposed. During such procedures, vascular tissues connecting the parathyroid gland to circulation may be damaged. Doctors must decide whether to reimplant the tissue or leave it in the thyroid bed; however, surgeons lack an objective measure to make such a determination.

Needs statement:

A means of assessing tissue viability is necessary, whereas perfusion of tissue is a chief indicator of such viability. The device should allow extremely rapid collection of data such that it may be used in surgical settings; consequently, an optical method will be required. Any optical technology should take care not to injure (ablate) sensitive parathyroid tissue. The device should build off of the success of previous devices intended to assist in thyroidectomies and parathyroidectomies: this eases obstacles that practitioner dogma poses and may encourage late adopters to consider the device. A modular device with high compatibility and easy integration with existing thyroidectomy and parathyroidectomy accessories is highly desirable. Regardless, such equipment must be compact and portable, such that it will not obstruct bench space or reduce ergonomics in a surgical environment. Lastly, producing a modular device will be cost effective as well.

Team Composition

The team working on this project is composed of senior level biomedical engineering students. Each member has completed the same core coursework, and the only differences are in

the electives and extracurricular research or employment positions. Itamar Shapira is the team's communication and organizational lead. He outlines the goals for each meeting to ensure the goals are completed in a timely manner. He also handles the communication between the advisors and keeps the rest of the team informed. James Tatum is the optics lead for the group. He has taken the biomedical engineering optics course and has the most experience regarding the fundamentals of lasers within the group. He ensures that the team receives the necessary education in the background material and suggests avenues of further scientific inquiry. Tianhang Lu is a double major in both biomedical engineering and economics. He has previous experience in product design and development. His role will primarily focus on the financial and marketing aspect of the project. Gabriela Caires de Jesus maintains documentation for the group and has experience with a diversity of imaging techniques. Yu Zhou has researched in the biophotonics lab and has worked with several methods of optical spectroscopy. He has an interest in the medical field and will be the medical lead for the group, maintaining contact with the medical personnel associated with the project.

The DISC profiles of the team members match up well with a balanced group. We have one D dominant profile and the rest are SC dominant or C dominant. This is a good balance mostly due to the single D (dominant) profile. Multiple Ds can negatively impact group productivity due to the controlling nature of that profile. The S profiles are perfect for pushing through the workload and the Cs are great for making sure everything is done correctly. Though we are missing the I personality, the group has a good level of cohesion which offsets the need for an I dominant person.

Project Advisors

There are three advisors who will be providing guidance on this project.

Dr. Anita Mahadevan-Jansen is Assistant Professor of Biomedical Engineering and is a leading expert on the use of laser spectroscopy to identify brain tumors.

Dr. Matthew Walker III holds the full time faculty Position of Associate Professor of the Practice of Biotechnology/Bioengineering at Vanderbilt University. His research includes unveiling systems level orthogonal biomarkers at the structure/function interface of disease.

Melanie McWade - Is a Biomedical Engineering PhD candidate in Dr. Mahadevan-Jansen's laboratory currently studying the fluorophore that gives thyroid tissue its high fluorescence.

History and Context

So far, we have conducted research on current vascularity identification techniques. A chart of candidate imaging solutions has been made and we are currently in the process of evaluating each solution. Following a meeting with our clinician, Dr. James Broome, the focus of our progress has pivoted to an examination of parathyroid gland perfusion as a main criterion of tissue viability in the thyroid bed. Dr. Anita Mahadevan-Jansen's biophotonics laboratory is currently testing a thyroid fluoroscopy device that can distinguish parathyroid tissue from thyroid tissue using near infrared spectroscopy (NIRS). Our first intended users will be practitioners at Vanderbilt University Medical Center (VUMC) currently using the fluoroscopy device to distinguish between thyroid and parathyroid tissue. These practitioners have a high patient volume for such procedures and their high levels of experience makes them optimal early adopters.

Work Process and Outcomes

The primary outcome of this project is to create a device that can determine the perfusion state of the parathyroid gland remaining in the thyroid bed, improving patient outcomes following endocrine surgery. This outcome must be met for the project to be considered

successful. In order to meet this outcome, several goals must be completed in order to have a functioning device. We must assess multiple imaging techniques and select an optimal method. POC must be verified in *ex vivo* experiments. Several optical methods of are currently under consideration, including spectroscopic techniques.

We are pursuing several secondary outcomes, including modular design and rapid data acquisition. Ideally, we intend to construct a modular component easily integratable with the current fluoroscopy device that is being tested by the Biophotonics department. A modular device will lower costs and increase the ease of acceptance by physicians already familiar with the fluoroscopy device. The device should allow for rapid data acquisition given its use in a surgical setting. The current fluoroscopy device requires three seconds to produce each of five or six measurements.

Evaluation and sustainability plan

The success of our project depends on the ability of our imaging device to determine perfusion state of parathyroid tissue in a clinical setting.

With respect to distinguishing perfused from unperfused tissue, our device must acquire a signal representing perfusion while filtering out distortion noise. Our method of detection may have a defined threshold in order to aid surgeons considering explantation and reimplantation. Also in evaluating our level of success, it is vital that our optical technology does not injure tissues. There are several existing candidate imaging solutions that might meet our criteria. Given this, the achievability creating a device capable making such determination of perfusion is feasible within the Senior Design project timeline.

Maintaining similar data acquisition times to the preceding fluoroscopy device is a measure of high success. Mechanical and data analysis integration with the preexisting fluoroscopy device will be a measure of high success.

Appendix

Budget

Our budget greatly depends on the method for determining perfusion. The optical probe price varies depending on the spectroscopy method used. The current fluoroscopy device uses a $5,000 probe while simple fibers (SiO_2) costs less than a dollar. In vivo specimens would be necessary for POC. We have permission to use all of the spectroscopy devices owned by Vanderbilt Biophotonics. If we determine that a device not owned by Vanderbilt is needed, then we would need to add that to the expenditures. Also, costs of possible future integration with current techniques could be part of the expenditure, but that is very far in the future.

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Tianhang (Kevin) Lu

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Current Address:
1215 15th Ave. South
Nashville, TN 37212

EDUCATION

Vanderbilt University, Nashville, TN
Double Major: Bachelor of Engineering in Biomedical Engineering
Bachelor of Arts in Economics
Expected Graduation Date: May 2014

WORK EXPERIANCE

Osto360, Nashville TN — Summer 2013
Biomedical Engineering Intern

- Integral part of the Research and Development team
- Identified materials and mechanisms that led to the successful proof of concept for a new product
- Developed first prototype for a new planned service
- Compiled and maintained a directory containing over 2000 relevant medical professionals
- Part of multiple investment pitches including the company's bid for Healthbox
- Maintained relationships with partners

Vanderbilt Dining — 2011 to 2012

- Food Server at CT West

Lumen Learning Center — 2009 to 2010

- Math tutor for students grade 1 through 12

EXTRACURRICULAR EXPERIENCE

Vanderbilt University Crew Team — 2010 to 2011

- Rower for the Vanderbilt Crew Team
- Dedicated 22 hours a week and over 800 total hours

Vanderbilt Students Volunteers for Science — 2012 to 2013

- Taught students at local schools
- Lead a group of 5 every week

Greater Cincinnati Chinese School — 2007 to 2010
Volunteer Director

- Founded the volunteering section
- Distributed responsibilities to other volunteers
- Dedicated 5 hours a week, 750 hours total

LANGUAGE SKILLS

- Fluent in Mandarin
- Studied Spanish for 4 years

COMPUTER SKILLS

- VB, C++, JAVA, MATLAB, Microsoft Office, LabVIEW, R Commander, Computer Hardware Installation

James Tatum

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Current Address:
Vanderbilt University
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2301 Vanderbilt Place
Nashville TN 37235 – 6307

Permanent Address:
6735 Spencer Forrest Cv E
Memphis, TN 38141

Education

Vanderbilt University, Nashville, TN
Bachelor of Engineering, Biomedical Engineering (August 2010 to May 2014)
Pre-medical

- Engineering GPA: 3.1/4.0

Coursework

Circuits I • Circuits II • Biomaterials • Linear Algebra and Differential Equations • Matlab
Systems Physiology • Fundamentals of Medical Imaging • Biological Basis of Imaging

Skills

- MatLab
- Mathematica
- Photoshop CS5
- Photography

Experience

Kelly Services at New Breed Logistics, Memphis, TN
Materials Handler (June 2012 to July 2012)

- Picked orders for New Breed Logistics
- Worked with a team of 10-14 pickers to complete 4000 to 8000 orders per day on schedule

Leadership

Vanderbilt Running Club
Practice Captain (January 2010 to Present)

- Designed workouts and led groups of 5-10 runners through Nashville
- Ensured all runners in my group completed the workout safely

Apparel Coordinator (January 2012 to Present)

- Designed t-shirts and running singlets for use by the club
- Worked with suppliers and other club board members to ensure everyone was satisfied with the product

Gabriela Caires de Jesus

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Vanderbilt University, PMB 350012
Nashville, TN

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(615) 602-6317

Permanent Address:
Rua Praia de Touros , 9135
Natal, RN, Brazil, 59092-110

EDUCATION

VANDERBILT UNIVERSITY, Nashville, TN
Exchange Student — September, 2013 to May, 2014
GPA: - / 4.0

FEDERAL UNIVERISTY OF RIO GRANDE DO NORTE, Natal, RN, Brazil
Bachelor of Engineering, Biomedical Engineering — February, 2010 to December, 2015
GPA: 3.5 / 4.0

RELEVANT PROJECTS

FEDERAL UNIVERISTY OF RIO GRANDE DO NORTE, Natal, RN, Brazil
Development and construction of a device to measure the conductivity of a solution
- The circuit was set up on a BreadBoard using basic electrical components — February, 2013 to June, 2013

Assembly of an ECG/EMG/EEG using basic electrical components — February, 2012 to July, 2012
- The device was assembled at a pre-printed circuit with basic electric components and the achieved signal was then filtered using software Pure Data

Article: "Atuação do Engenheiro Biomédico no Hospital Universitário Onofre Lopes" — October, 2012
- "Performance of the Biomedical Engineer at the University Hospital Onofre Lopes"
- Article presented at the 18th CIENTEC – Week of Science, Technology and Culture

Development of a Matlab script to evaluate the gait — February, 2012 to July, 2012
- The script was generate using the Robotics Toolbox
- Data from joints was used to simulate a robot in order to achieve quantitative information about the gait

WORK EXPERIENCE

DISTANCE EDUCATION SECRETARIAT OF THE FEDERAL UNIVERSITY OF RIO GRANDE DO NORTE
Test analyzer — November, 2012 to July, 2013
- Worked testing the software that was developed to coordinate all the courses of the Distance Education at the University
- Was part of the customer support team

FEDERAL UNIVERSITY OF RIO GRANDE DO NORTE
Assistant of the Brazilian Robotics Olympiad — May, 2010 to December 2010
- Collaborated with the organization of the Brazilian Robotics Olympiad

CCAA – Anglo-American Cultural Centre
English Teacher — September, 2009 to July, 2010
- Worked as an English teacher mostly for kids and teenagers

SOCIAL EXPERIENCE AND SPORT

Kung Fu Classes — May, 2012 to February, 2013

COURSEWORK

VANDERBILT UNIVERSITY
Biomedical Instrumentation ● Design of Biomedical Devices and Systems I ● Senior Engineering Design Seminar ● Image Processing ● Introduction to Tissue Engineering

TECHNICAL SKILLS

Matlab ● MS Office Suite

LANGUAGES

Itamar Shapira
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DOB: July 2, 1993

Educational History:

Virgil I. Grissom High School
7901 Bailey Cove Rd SE
Huntsville, AL 35802
(256) 428-8000
Attended: Freshman - Senior

University of Alabama at Birmingham (UAB)
Birmingham, Alabama, 35294
Attended: First year Undergraduate

Vanderbilt University
Nashville, Tennessee, 37240
(615) 322-7311
Attended: Second year Undergraduate-Present

Major: Biomedical Engineering

Awards/Honors/Achievements:

First Year:

Science and Technology Honors Program
Alpha Lambda Delta Honor Society (Top 5% Freshman Class)
Freshman Forum Member (UAB USGA)
UAB Golden Excellence Scholarship
UAB Presidential Honors (both semesters)

Second Year:

Fueling Innovation Forum Summer 2013 (UAB Science and Technology Honors Program)

Third Year:

[On track to become] Fastest graduate of Vanderbilt Undergraduate Biomedical Engineering Department

Research Experience:

First Year:

Student Researcher in lab of Dr. Ho-Wook Jun, Fall 2011/Spring 2012
Biotechnology and Research Applications Course, Spring 2012

Second Year:

Student Researcher in lab of Dr. Elizabeth Sztul Summer 2013

Skill Set Specifics

Familiarity or competence with the following biological laboratory techniques:

- Basic biotechnology: PCR, Agarose Gel Electrophoresis, Polyacrylamide Gel Electrophoresis, Bacterial Plating, Ligation, Transformation, Plasmid DNA Isolation, Spectroscopy, Restriction Enzyme Digest, Protein Isolation, Cell Culture

Competent:

-Statistics, Word, Excel, Powerpoint, MATLAB Scripting, Creo Parametric Solid Modeling, Engineering design, Scientific/Technical writing

Extra-curricular Activities:

First Year:

Freshman Forum Member (UAB USGA)
- Student Issues Board
Biomedical Engineering Society (BMES)

Second and Third Years:

Vanderbilt Hillel
-Religious Life Committee member
-Hillel Israel Committee member
-Founder of Tiyul (Hillel's first Jewish outdoors group)
Dores for Israel (pro-Israel political advocacy organization)
-Attendee to AIPAC Saban conference in Washington, D. C., January 2013, July 2013
-Attendee to AIPAC Policy Conference in Washington, D. C., March 2013
Chabad Jewish Student Organization
-Chabad Student Board

Miscellaneous:

Multilingual (fluent in Hebrew and English; some French and German)
Avid runner

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Yu Zhou

Academics

Vanderbilt University
Current major: Biomedical Engineering GPA: 3.636
Year of graduation: 2014 Hours earned: 116.0 Quality hours: 88.0

Extracurricular Activities

Aug 10 to Present — **Vanderbilt Rowing Team** (18 Hrs/Week + Competition on weekends)

Team President: liaison to the University, approves all team funds and monitor team finances, leads recruitment and fundraisers, organize and run board meetings

Varsity Rower: Rowed in the top varsity boat for the past 2 years, rowed in the top freshmen boat freshmen year. Competed in nationwide regattas including Head of the Charles (world's largest two-day regatta), championship events in the Head of the Hooch (second largest regatta in U.S: champ 4+ and champ 8+).

ACRA: American Collegiate Rowing Association (national club rowing competition)
15th (novice 8+, 2011) 16th (varsity 8+, 2012) 18th (varsity 8+, 2013)
2-time ACRA Second Team Academic All-American

Research

Jan 11 to May12 — **The SyBBURE Searle Undergraduate Research Program** (10Hrs/Wk)

SyBBURE stands for Systems Biology and Bioengineering Undergraduate Research Experience

Two paid research projects in the SyBBURE microfluidics lab:

Independent project: Finding a cheaper and more hydrophobic alternative to dialysis membrane using block co-polymers and infused porogens. The filter is designed for improved reading of mass spectrometry of biological samples.

Team project: Building a microfluidic device that tracks over 40 generations of yeast cells (10^{12} number of cells) to determine the mechanisms of cell aging. My part in the project is in the design and fabrication of the yeast tracking device

May 12 to Aug' 12 — **Research Assistant in the Department of Biophotonics** (40Hrs/Wk)

The focus of the research is the development of optical spectroscopy for diagnosis of disease and guidance surgery. My involvement is the characterization of bone matrix properties of breast and prostate bone metastasis in mice. I identified the characteristic patterns of cancerous bone metastasis in mice.

Volunteer Service

Jan '12 to May 12 — **Monroe Carell Jr. Children's Hospital Volunteer** (2Hrs/Wk)

Part of a national reading program. Job includes reading books in the waiting room to children demonstrating to parents and caregivers how to read to children. Also encouraged visiting families to sign up for Tennessee reading programs, that sends books to children to encourage reading and improve literacy. (2 Hours/Week)

Additional Supporting Documents

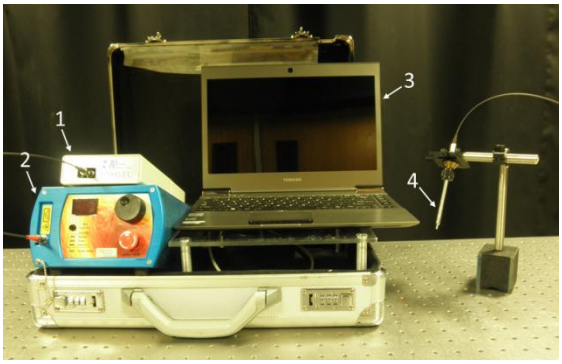

Figure: Near-infrared fluorescence spectroscopy system showing a (1) spectrometer, (2) 785-nm diode laser, (3) laptop computer, and (4) hand-held fiber optic probe. (Courtesty of Mahadevan-Jansen laboratory)