The primary purpose of this peer-reviewed journal is to provide a formal publication option for research completed by MSUCOM students, residents and faculty. SMRJ's mission is to advance medicine and medical education through the timely publication of peer-reviewed clinically-oriented research, clinically-relevant basic science research, healthcare quality research, and medical education research from MSUCOM and the osteopathic medicine community, with the ultimate goal of improving patient care and the education of patients and care providers. SMRJ is the official scholarly publication of the Statewide Campus System (SCS) of MSUCOM. It provides a forum for communicating research findings, clinical practice observations, philosophic concepts, and other biomedical and medical education advances to MSUCOM medical students, residents, fellows and faculty, and any other interested readers.

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Table of Contents

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From the Editor
iv  Welcome to our third issue

Original Contribution
1  Factors Associated with Disordered Eating Behavior among Triathletes
Samantha Fugate Kennedy DO, Alyse Folino Ley DO, Brianna Nicole Fugate EdS, MA, Alexander Hayek OMS III

15  The Influence of Social Isolation and Medical Comorbidities on Geriatric Congestive Heart Failure Hospital Readmissions
Daniel Keyes MD, MPH, Greg Sheremeta MPH, Jerrit Yang BS, Naomi Davis MD, MPH, Shiling Zhang MS, Kevin Boehm DO

30  The Use of Magnetic Resonance Cholangiopancreatography (MRCP) in the Setting of Acute Pancreatitis: When is it Most Useful?
Karlin Sevensma DO, FACOS, Miranda Allen DO, Rebecca Harden DO, William Corser PhD

Case Series
43  Robot Assisted Repair of Acquired Abdominal Intercostal Hernias (AIH)
Daniel Smith DO, Mohan Kulkarni MD, FACS, Shawn Obi DO, FACS

Case Report
57  A Fatal Case of Neuroinvasive West Nile Virus Infection in an Immunocompromised Host
Justin Allen DO, Jennifer Conard DO, Michael Wang MD

64  Removal of Misplaced Left Ventricular Single Lead Pacemaker in a Patient Presenting with Recurrent Transient Ischemic Attacks
Andrew Hinojos DO, Karl Ilg MD

(CONTINUED ON NEXT PAGE)
Case Report

74 Laproscopic Paraesophageal Hernia Reduction with Two Point Fixation via Ponsky PEG Tube in a Patient in their Early 90s
Catherine T. Petzinger DO, John Parmely DO, FACOS

86 Carbon Monoxide Poisoning: The Great Imitator
Christopher Velasquez MS4, Tye Patchana MS4, Brian McParland MS4, Jonathan Lovy DO, Ahmad Maarouf MD, Christopher Whitty PhD, MD

Brief Report

98 Thermal Energy Produced by Medium Velocity Pistol Projectiles and the Effects on Peripheral Nerve Tissue
Alexander J. Colen DO, Logan F. Hanson DO, Germaine R. Frits DO, Cameron G. Hanson BS
Welcome to Issue One of our 2017 Journal Volume!

We’d like to welcome you to the first issue of Volume Two of The Spartan Medical Research Journal (SMRJ)! We have the distinct pleasure of serving as your Editorial Office team for this issue.

As noted inside the cover of this issue, the purpose of our online peer-reviewed journal is to provide a convenient, formal publication option for research/quality improvement project papers with some clinical case reports from both Michigan State University COM students, residents, fellows and faculty and scholars outside of the MSU community. We continue to receive submissions from both SCS-affiliated and non-affiliated researchers from other states.

Those of us at the Statewide Campus System continue to be dependent on a large number of colleagues to generate these journal issues, especially from our growing number of expert reviewers. Our editorial office team offer many thanks to those experts who reviewed these nine Volume 2(1) submissions. We are still recruiting expert reviewers from all medical specialty areas to be members of our SMRJ Editorial Board. If you have an interest in participating as a reviewer, please contact Chief Editor Corser.

If you have comments or suggestions, also please feel free to contact us at any time. Please remember that we also accept Letters to the Editor submissions. We hope that you enjoy reading this issue!

Sincerely,

Bill Corser, PhD, RN, NEA-BC
Chief Editor
Corser@msu.edu
(517) 918-3470

Sam Wisniewski, MS
Assistant Editor

Luke Sandel
Manuscript Editor and Website Coordinator
Factors Associated with Disordered Eating Behaviors among Triathletes

Samantha Fugate Kennedy DO,1 Alyse Folino Ley DO,2
Brianna Nicole Fugate EdS, MA,3 Alexander Hayek OMS III 3

1 Michigan State University Department of Psychiatry, Resident, East Lansing, MI.
2 Michigan State University Department of Psychiatry, Residency Director, East Lansing, MI.
3 Eaton Regional Education Service Agency School Psychologist, Charlotte, MI.
4 Michigan State University College of Osteopathic Medicine, Osteopathic Medical Student, East Lansing, MI.

Corresponding Author: Samantha Fugate Kennedy DO, Samantha.Kennedy@hc.msu.edu

ABSTRACT

KENNEDY SF, LEY AF, FUGATE BN, HAYEK A. Factors Associated with Disordered Eating Behaviors among Triathletes. Spartan Med. Res. J. Vol. 2, No. 1, pp. 1-14, 2017. CONTEXT: Although there is little data currently available concerning the primary factors associated with disordered eating behaviors among triathletes, these athletes may be at greater risk. Sports medicine professionals are in a unique position to identify athletes with disordered eating risks. METHODS: The purpose of this cross-sectional survey study was to identify the prevalence of disordered eating attitudes and behaviors among a national convenience sample of triathletes. A secondary purpose was to identify “triathlon-specific factors” and “competitive athlete-factors” potentially associated with disordered eating behaviors. The authors hypothesized that certain triathlon-specific factors and competitive athlete factors would be associated with increased rates of self-reported disordered eating behaviors. RESULTS: In a respondent sample of 1,033 adults, multiple competitive athlete factors were associated with a higher risk for disordered eating, whereas triathlon-specific factors were not. CONCLUSIONS: In this study sample, disordered eating was not specifically associated with triathlon-specific factors. Rather, disordered eating behaviors were found to be more often associated with associated competitive athlete factors, particularly in the many leanness sports such as running. Keywords: disordered eating, anorexia nervosa, bulimia nervosa, athletes

INTRODUCTION

The prevalence of eating disorders in women in the general population is estimated to be less than 1% for anorexia nervosa (AN), 1-2% for bulimia nervosa (BN) and 3-5% prevalence of partial syndromes.1 The current edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) defines AN as a syndrome consisting of restriction of calories leading to significantly low body weight, intense fear of gaining weight and disturbance of the perception of one’s body.2 Partial syndromes of eating disorders
Factors Associated with Disordered Eating Behavior among Triathletes

consist of symptoms that cause clinically significant impairment, but do not meet the full criteria for AN or BN.

In the DSM-5, BN is defined as a syndrome consisting of recurrent episodes of binge eating and recurrent inappropriate compensatory behaviors to prevent weight gain, both occurring at least once a week for two months with self-evaluation influenced by body weight and shape. The prevalence of eating disorders in males is significantly lower with a male-female ratio for likely under-reported eating disorders estimated between five and 10%.

In athletes, the overall prevalence of eating disorders is higher than the general population, as well as in female athletes and sports that emphasize leanness such as triathlons. Triathlons are comprised of three sports, swimming, biking and running, in which disordered eating (DE), which encompasses a spectrum of abnormal behavior ranging from mild preoccupation with food and exercise to a diagnosis of AN or BN according to the DSM-5, has been reported. Triathlons are also one of the most rapidly growing sports in the United States.

The governing body of triathlon events in the United States, USA Triathlon (USAT), tracks triathlon participants throughout the country. During the past 10 years, the annual number of purchased USAT memberships has increased from 47,373 in 2003 to 170,033 in 2014. Based on studies to date, this growing group of triathletes may be at higher risk for DE.

For example, in one study using the definition of the “female athlete triad,” 60% of 15 sample women triathletes with ages between 29 and 41 years were in a calorie deficit. In that study, criteria established prior to re-identification in 2007 by the American College of Sports Medicine were used, which identified a calorie deficit for female athletes as a syndrome characterized by DE, amenorrhea and low bone mineral density. Another study investigating eating behaviors in 188 women triathletes (mean age 35 years) found insufficient caloric intake for energy requirements.

Another study investigating sub-clinical DE characteristics among 393 men (mean age 38 years) and 188 women (mean age 35 years) triathletes showed 58% of the women and 47% of the men reported being dissatisfied with how they perceived their weight.
There may be factors that are unique to triathlon that may contribute to the risk for DE along with factors that can be found in several sports.

Triathlons are generally divided into male and female divisions and have qualifying event criteria which enable amateur athletes to also qualify for national and world championship events. This categorical system of triathlon eligibility may result in increased competitiveness as only a small percentage of triathletes can win a podium placement at championship events. This could put increased pressure on triathletes to perform and thus potentially increase risk for DE.

Triathletes are training more and racing longer distances more frequently than in the past.9 Distance race categories include Sprint, Olympic, Half and Full (see Table 1). Although the sprint distances are the most popular, triathletes’ desire to participate in the longest distances appears to increase with experience.14 The increased amounts of training typically required for athletes to finish longer triathlons may be associated with higher risk for DE.13

Nearly one-third (29%) of triathletes utilize some form of structured coaching.13 Previous studies have shown that coaches’ possible weight loss recommendations can have a significant influence on athletes.15 Additionally, research has shown the opinions of those involved with athletes, including parents, trainers and coaches, can significantly influence an athlete’s opinion of their weight and have an impact on their risk for DE.16

Currently, there is little available data concerning DE in triathletes. The purpose of this cross-sectional survey study was to identify the prevalence of DE attitudes and behaviors among a national convenience sample of triathletes. A secondary purpose was to identify “triathlon-specific factors” and “competitive athlete-factors” potentially associated with DE behaviors. (These factor groups will be defined in the Methods section).

Although the vast majority of triathletes are amateur triathletes, the authors hypothesized that certain factors unique to triathlon and competitive athlete factors would be associated with increased rates of DE.
Factors Associated with Disordered Eating Behavior among Triathletes

METHODS

Before data collection, the study had been approved by the Michigan State University Human Research Protection Program. Informed consent language was located on the first page of the survey listing contact information of the researchers and the overall purpose of the study. The first page also outlined that respondents needed to be at least 18 years of age and a current active triathlete in the United States. By completing any or all parts of the survey, participants were interpreted as providing their informed consent. To encourage accurate self-reporting, responses were anonymous.

The online survey link was circulated by emailing an unspecified number of triathlon teams and elite/professional triathletes. Additionally, the survey link was spread on social media, including Facebook and Twitter. Data were exported from Google Form Survey 17 software into IBM SPSS Statistics Edition 23 18 for statistical analysis by author Alexander Hayek. The respondent sample was divided into male and female participant subgroups and each set of data was analyzed separately. A chi-square test of independence was performed for each of the triathlon-specific and competitive athlete factors with the Eating Attitudes Test (EAT-26) 19 scores treated as a continuous outcome.

The EAT-26 is a standardized self-report measure comprised of three subscales: Dieting, Bulimia, and Food Preoccupation.20 The response scale for the EAT-26 items utilizes a six-point Likert Scale: “Never,” “Rarely,” “Sometimes,” “Often,” “Usually” and “Always.” A score of 20 or greater indicates risk for DE.19 The total possible score range for the EAT-26 was 0 through 76. For this study, triathletes with a score of 20 or greater were considered to possess some form of DE. The authors’ hypothesized relationships were considered significant if their coefficient Alpha p-value was lower than 0.05.

The triathlon-specific factors that were evaluated included:

- Race Category
- Age Group
- Collegiate, or Elite/Professional status
- Overall Triathlon Finish Category (i.e., top, middle or bottom)
- Championship Qualification Category
- Selected Race Distance
• Years of Triathlon Experience
• Number of Triathlons Per Year
• Sponsorship

The competitive athlete-factors factors that were assessed included:

• Number of sports-related injuries during the past season
• Degree of worry about weight gain during the off season
• Whether or not an athlete was happy with his or her current weight
• Desired amount of weight loss to improve performance
• Specific people who have told the respondent to lose weight (e.g., coach, family member, other triathlete)
• Specific methods of weight loss (e.g., specific dietary restrictions, increase in training volume, increase in training intensity).

The statistical significance of relationships between EAT-26 scores (with a positive EAT-26 score indicating risk of DE) and the triathlon-specific and competitive athlete factors across the vast majority of sports were examined.

The software package GPower 3.0 \(^{21}\) was used to conduct a post-hoc power analysis. The sample size of N=1033, at an alpha level of p < 0.05, and recommended effect sizes parameters of small (w=.1), medium (w=.3), and large (w=.5) were used for the statistical power analyses.\(^{22}\) The post-hoc analyses revealed the statistical power for this study was .90 for detecting a small 0.1 effect, and the overall power exceeded .99, much more than the generally observed 1- \(\beta\) minimal level of adequate statistical power (i.e., power of 0.80) to detect meaningful sample subgroup differences.

**RESULTS**

A total of 1,033 surveys were completed online and included in the study analyses with largely complete data. However, it is unknown how many surveys may have been initially started but never completed. There were no exclusion criteria observed.

Responding participants included 1,033 triathletes (545 (52.8%) women and 488 (47.2%) men). In terms of 928 respondents’ race age group, there were 435 (46.8%) men, and 493 (53.1%) women. There were 107 (10.3% of total sample) race collegiate
Factors Associated with Disordered Eating Behavior among Triathletes

(54 men, 53 women) and 70 (6.8%) race elite/professional (34 men, 36 women). There was some reported overlap in these findings between triathlon racing categories because collegiate athletes can also race by age group and elite/professional athletes can race in some collegiate and age group triathlons. This and other socio-demographic information concerning the sample is depicted in Table 2.

The authors found that 129 (12.5%) of respondents scored positive on the EAT-26 and 284 (27.5%) were concerned they have an eating disorder or had been diagnosed with an eating disorder. Rates of DE were higher among women ($p < 0.001$) and triathletes in the 18-19 age group ($p < 0.001$). Although the rate was highest in the 18-19 age group, it was also imperative to assess DE among other age groups as only 10 (7.8%) of the 129 positive EAT-26 scores belonged to athletes in the 18-19 age group. There was no significant relationship found between positive EAT-26 scores and a total of 12 former sports ($p$ values ranging from $p = 0.80$ to $0.06$).

The authors had expected a relationship between triathletes who had previously competed in sports that emphasized leanness, such as running, which has been shown in previous research.\textsuperscript{23,24} There was no significant relationship between positive EAT-26 scores and the category “one to two injuries” during the previous season ($p = 0.300$). There was a significant relationship for the category “three or more injuries or season ended early due to injury” ($p < 0.001$). With regards to weight loss, there was no significant relationship found between positive EAT-26 scores and the categories “0.45 to 2.3 kg” ($p = 0.310$), “2.3 to 4.5 kg” ($p = 0.190$), and “4.5 to 6.8 kg” ($p = 0.180$). There was a significant relationship for the category “6.8+ kg” ($p = 0.002$). For methods of weight loss, there was no significant relationship for the category “Increase training hours of intensity” ($p = 0.06$).

The percent of male and female triathletes for each BMI category (underweight <18.5, normal weight 18.5-24.9, overweight 25-29.9 and obese 30+) were calculated for each of the weight-related factors. These response categories included “unhappy with current race weight,” “told to lose weight by someone who is not a physician” and “told to lose weight by a physician” (Table 3). Multiple participants answered “doctor” or “physician” for the “other” choice on the item “Have you ever been told to lose weight?” survey question. Thus, a new category, “Physician,” was created for project analysis.
There was no significant relationship between being told to lose weight by a physician and a positive EAT-26 score, although all other answer choices were significant for women triathletes, including “Coach,” “Another Triathlete,” and “Family Member” (Table 4).

There was also a significant relationship between triathletes who have been diagnosed with an eating disorder or are concerned they have an eating disorder and a positive EAT-26 score (p < 0.001). The authors believe that it is important for readers to consider that 44 (5.7%) sample triathletes who answered “No” to this question had a positive EAT-26 score. This underscores the authors’ assertion that DE or related symptoms/behaviors were often underreported in the sample.

The majority of triathlon-specific factors did not have a significant relationship with a positive EAT-26 score whereas several of the competitive athlete factors did demonstrate a significant relationship with a positive EAT-26 score (Table 4). Of the triathlon-specific factors, only “Olympic” in the category “Race Distance” was found to have a significant relationship with a positive EAT-26 score (p = 0.04). However, the authors believe that this p-value may have been artificially inflated due to the percentage of participants with positive EAT-26 scores in the Olympic category who also reported concerned they have DE or had been diagnosed with an eating disorder (62.5%, of eight respondents) was much higher than the percentage of all study respondents (27.5%).

DISCUSSION

The results of our study indicated that triathlon-specific factors in this sample were not significantly associated with DE, although competitive athlete factors were associated with DE. Although previous studies have concluded that triathletes may be at higher risks for the onset and maintenance of DE,7,12,13 these results suggest that triathlon by itself is not associated with DE. In this study, 129 (12.5%) participants were considered to have DE and 284 (27.5%) were concerned they have an eating disorder or had been diagnosed with an eating disorder.

It should be noted that 964 (93.3%) sample respondents were amateur triathletes and only 87 (9.0%) age group triathletes reported having a precise training plan similar to elite/professional triathletes.14 Although age group triathletes were not competing in the
elite/professional category, these athletes may be at increased risk for DE due in part to the commonly shared competitive factors associated with DE.

The selected competitive athlete factors included in this design were intended to evaluate the importance of leanness in relation to performance. Leanness has been linked to improved performance in all three disciplines that comprise triathlon. Due to the uniqueness of this combination of disciplines, triathletes may have increased body size dissatisfaction. For example, a study of 487 girl and 468 boy swimmers aged between 9 to 18 found that 75 (15.4%) of the girls and 17 (3.6%) of the boys reported engaging in pathogenic weight control behaviors.16

Another study of 61 competitive men cyclists (Mean age 31.6 years) found 12 (19.6%) had DE.27 Finally, a study of 181 elite women runners with mean age 29 years found 29 (16%) respondents had DE and 36 (20%) had eating disorders not otherwise specified (DSM-5).28 In our study, there was a significant relationship between women former runners and a positive EAT-26 score (p = 0.04).

In our study sample, the majority 566 (54.8%) answered that they are in some way not happy with their current race weight. The majority of both men and women participants who were unhappy with their weight were, however, normal weight or underweight (Table 3). This body dissatisfaction and desire to lose 6.8 kg or more was significantly associated with DE in women triathletes (p = 0.001) and may be due to drive for leanness as triathletes attempt to achieve lower racing weights or ideal body types.

Additionally, specific methods utilized to lose weight, such as low carbohydrate, low sugar and low fat diets, were associated with DE. Of triathletes with a positive EAT-26 score, 98 (93.3%) of female triathletes and 98 (95.8%) of male triathletes (23 of 24) followed a specific diet (Table 4). The formulation of these diets may represent restrictive eating tendencies and emphasize a good food/bad food structure, which is a known to eventually lead to eating disorders.25,29

DE behaviors can lead to poor nutritional status which may result in increased injuries.30 In this sample, triathletes with three or more injuries during the past season were more likely to have positive EAT-26 scores. Additionally, triathletes who have suffered from an injury that ended their prior season prematurely were more likely to be at risk for DE. Therefore, injury frequency during the past season should be considered
by sports medicine professionals when evaluating triathlete patients for DE. Reported concerns about gaining weight daily or constantly during the off season or when the triathlete is injured and cannot train was also associated with DE. However, worry about weight gain a little or a few times per week was significantly associated with negative EAT-26 scores. Thus, worry about weight gain a little or a few times per week may indicate a lower risk for DE.

Another factor associated with DE was whether or not a female triathlete had been told or recommended to lose weight. Whether it was a coach, another triathlete or a family member, women triathletes who had been told to lose weight were more likely to have DE (p = 0.01, p = 0.001, and p <0.01; respectively). Of those recommended to lose weight by someone who was not a physician, 50 (42%) of 118 men and 116 (72%) of 143 women were reportedly underweight or normal weight (two far right columns in Table 3).

On the other hand, of those recommended to lose weight by a physician, 24 (83%) of 29 men and 27 (71%) of 38 women reported themselves as being overweight or obese. This is likely because physicians recommend weight loss when a patient is at risk for health complications associated with obesity, whereas triathletes may receive input from coaches regarding body leanness or composition to improve performance. Previous research has shown coaches have significant influence with athletes and coaching style can increase risk for DE and body dissatisfaction. These study results suggest that other triathletes and family members can also have an impact on an athlete’s perception of weight. This may also be compounded by triathletes wishing to race faster and believing increased body leanness will result in improved performance.

This study had several limitations. Due to the cross-sectional design of the study, there may be an excess in prevalence due to long duration of eating disorder cases. The purpose of the study was clearly stated when the survey was administered, which may have caused triathletes with a personal history of or connection to DE to be more or less inclined to complete the survey due to perceived response non-response biases. In addition, this was a self-report survey and thus the answers given may not be entirely accurate.

Another limitation is that the national triathlete population was not proportionately represented in this sample, as only 36.52% of USAT members in 2013 were women and
Factors Associated with Disordered Eating Behavior among Triathletes

545 (52.8%) of sample participants were women. Thus, results may be skewed as eating disorders are more prevalent in females than in males. Additionally, the number of men triathletes with positive EAT-26 scores was relatively small (N=24) compared to the number of women triathletes with positive scores (N=105), thus making analysis of features in men triathletes more difficult to generalize to the entire triathlete population.

CONCLUSIONS

These overall findings suggest that most triathletes can continue to have healthy attitudes about their weights and shapes even when they are competitively racing longer distances. Additionally, these results suggest that triathletes can compete for long periods of time and race more frequently without increased association with DE.

Although triathlon participation by itself was not associated with an increased rate of DE, many triathletes in this study reported competitive athlete factors that were associated with increased rates of DE. Competitive athlete factors are relatively well known to occur in elite runners,28 even though responses from this study sample suggests that these factors can occur in all levels of triathlon and may be associated with DE.

Professionals who work closely with athletes on a regular basis (e.g., sports medicine physicians, osteopathic manipulative medicine practitioners and athletic trainers) may have an opportunity to prevent progression from DE to eating disorders as the first professionals to see triathletes with frequent injuries. These professionals may often be in a unique position to screen athletes for DE and facilitate treatment. Future studies to develop and test further methods of identifying and treating triathletes with DE is vital.

The authors report no external funding source for this study.
The authors declare no conflict of interest.
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Accepted for publication July 2017
REFERENCES


### Table 1: Triathlon Distance Categories

<table>
<thead>
<tr>
<th>Race distance</th>
<th>Swim length</th>
<th>Bike length</th>
<th>Run length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprint*</td>
<td>750 m</td>
<td>20 km</td>
<td>5 km</td>
</tr>
<tr>
<td>Olympic</td>
<td>1500 m</td>
<td>40 km</td>
<td>10 km</td>
</tr>
<tr>
<td>Half Distance</td>
<td>1.93 km</td>
<td>90.12 km</td>
<td>21 km</td>
</tr>
<tr>
<td>Full Distance</td>
<td>3.86 km</td>
<td>180.24 km</td>
<td>42.16 km</td>
</tr>
</tbody>
</table>

* Sprint distance triathlons are not always the standard distance.

### Table 2: Socio-demographic Sample Characteristics

<table>
<thead>
<tr>
<th>Age group</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total,a N (%)</td>
<td>453 (89.1)</td>
<td>493 (90.5)</td>
<td>81 (11)</td>
<td>53 (9.7)</td>
<td>52 (6.9)</td>
<td>36 (6.6)</td>
</tr>
<tr>
<td>Mean age,b (years)</td>
<td>41.3±11.3</td>
<td>39.3±11.2</td>
<td>23.8±3.3</td>
<td>22.5±3.3</td>
<td>30.5±5</td>
<td>30.5±7.7</td>
</tr>
<tr>
<td>Mean BMI, (kg/m²)</td>
<td>24.5±3.2</td>
<td>22.9±3.9</td>
<td>23.1±2.8</td>
<td>21.9±2.6</td>
<td>22.6±2.7</td>
<td>20.8±1.8</td>
</tr>
<tr>
<td>Concern/diagnosis ED, N (%)</td>
<td>52 (12)</td>
<td>174 (35.3)</td>
<td>4 (7.4)</td>
<td>24 (45.3)</td>
<td>7 (20.6)</td>
<td>23 (63.9)</td>
</tr>
<tr>
<td>Received treatment, N (%)</td>
<td>4 (0.9)</td>
<td>64 (13)</td>
<td>0 (0)</td>
<td>10 (18.9)</td>
<td>3 (8.8)</td>
<td>12 (33.3)</td>
</tr>
<tr>
<td>Positive EAT-26,19 N (%)</td>
<td>23 (5.3)</td>
<td>95 (19.3)</td>
<td>1 (1.9)</td>
<td>10 (18.9)</td>
<td>1 (2.9)</td>
<td>9 (25)</td>
</tr>
</tbody>
</table>

a. There is overlap between categories as Collegiate triathletes can race Age Group and Elite/Professional License triathletes can sometimes race Age Group.

b. Mean age was calculated using mean age from participant’s age group, which is 18-19, then 5 years intervals (20-24, 25-29, etc.) until the 70+ age group, for which 70 was used.
Table 3:
BMI Frequencies for Weight-Related Questions

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Underweight</td>
<td>Normal Weight</td>
<td>Overweight</td>
<td>Obese</td>
</tr>
<tr>
<td>Unhappy with weight, N (%)</td>
<td>&lt;18.5</td>
<td>18.5-24.9</td>
<td>25-29.9</td>
<td>30.0+</td>
</tr>
<tr>
<td>Male</td>
<td>2 (0.8)</td>
<td>203 (81.9)</td>
<td>35 (14.1)</td>
<td>8 (3.2)</td>
</tr>
<tr>
<td>Told to lose weight, N (%)</td>
<td>0 (0)</td>
<td>50 (42.4)</td>
<td>54 (45.8)</td>
<td>14 (11.9)</td>
</tr>
<tr>
<td>Female</td>
<td>8 (2.5)</td>
<td>226 (71.1)</td>
<td>62 (19.5)</td>
<td>22 (6.9)</td>
</tr>
<tr>
<td>Told to lose weight by physician, N (%)</td>
<td>0 (0)</td>
<td>11 (2.6)</td>
<td>17 (24.3)</td>
<td>10 (43.5)</td>
</tr>
</tbody>
</table>
| a. Percent of those unhappy with current weight | b. Told to lose weight by coach, another triathlete or family member.
| c. Percent of those told to lose weight by someone who is not a physician | d. Percent of those told to lose weight by a physician |

Table 4:
Competitive Athlete Factors and Association with EAT-26 \(^{19}\)
Score of 20 or Greater

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (%)</td>
<td>p</td>
<td>N (%)</td>
<td>p</td>
</tr>
<tr>
<td>Told to lose weight by</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coach</td>
<td>3 (12.5)</td>
<td>0.65</td>
<td>20 (29.4)</td>
<td>0.02</td>
</tr>
<tr>
<td>Another triathlete</td>
<td>4 (16.7)</td>
<td>0.25</td>
<td>16 (48.5)</td>
<td>24.3</td>
</tr>
<tr>
<td>Family member</td>
<td>2 (8.3)</td>
<td>0.54</td>
<td>27 (31.8)</td>
<td>0.001</td>
</tr>
<tr>
<td>Injuries during previous season</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 or more injuries or season ended due to injury</td>
<td>5 (20.8)</td>
<td>0.02</td>
<td>25 (45.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Worry during offseason or when cannot train</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Little to few times per week</td>
<td>6 (25)</td>
<td>0.001(^c)</td>
<td>14 (4.7)</td>
<td>&lt;0.001(^c)</td>
</tr>
<tr>
<td>Daily or constantly</td>
<td>17 (70.8)</td>
<td>&lt;0.001</td>
<td>91 (43.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Unhappy with weight</td>
<td>14 (58.3)</td>
<td>0.30</td>
<td>88 (27.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Amount of weight loss desired</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.8+ kg</td>
<td>3 (12.5)</td>
<td>0.51</td>
<td>20</td>
<td>0.002</td>
</tr>
<tr>
<td>Method of weight loss</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific diet</td>
<td>23 (95.8)</td>
<td>&lt;0.001</td>
<td>98 (26.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>a. Percent reported is out of EAT-26 (^{19}) scores of 20 or greater (N=24)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Percent reported is out of EAT-26 (^{19}) scores of 20 or greater (N=105)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Significant that Little or Few associated with negative EAT-26 (score &lt;20)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. Combination of counting calories, restricting calories, low carbohydrate, low fat, low sugar, high protein and diet pills</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Influence of Social Isolation and Medical Comorbidities on Geriatric Congestive Heart Failure Hospital Readmissions

Daniel Keyes MD, MPH,1,2,3,4 Greg Sheremeta MPH,3,5 Jerrit Yang BS,1 Naomi Davis MD, MPH,6 Shiling Yang MS,1 Kevin Boehm DO 1,2,3

1 St Mary Mercy Hospital Emergency Medicine and Graduate Medical Education Research, Livonia, MI
2 St Mary Mercy Hospital Department of Emergency Medicine, Livonia, MI
3 Michigan State University School of Osteopathic Medicine, East Lansing, MI
4 University of Michigan School of Medicine, Ann Arbor, MI
5 College of Podiatric Medicine and Surgery, Des Moines University
6 University of Texas Rio Grande Valley (UTRGV) School of Medicine, Department of Family and Community Medicine

Corresponding Author: Daniel C. Keyes MD, MPH, keyesdc@trinityacademichealth.org

ABSTRACT

KEYES D, SHEREMETA G, YANG J, DAVIS N, YANG S, BOEHM K. The Influence of Social Isolation and Medical Comorbidities on Geriatric Congestive Heart Failure Hospital Readmissions. Spartan Med. Res. J. Vol. 2, No.1, pp. 15-29, 2017. CONTEXT: Social isolation and comorbidities are likely to have a significant level of influence on the healthcare use patterns of geriatric patients with ongoing congestive heart failure (CHF)-related needs. METHODS: A retrospective study was conducted in a specialized emergency department (ED) with a sample of 286 geriatric CHF patients who initially received CHF-related care over a six-month period. Social isolation levels were assessed using a pre-existing four-point screening tool used in the study setting and composite comorbidity was gauged using the Charlson Comorbidity Index method. Subjects were categorized into either “less than 30-day readmission” or “greater than 30-day readmission/non-readmitted” sample subgroups. The setting was a single 304-bed community hospital with approximately 45,000 annual ED visits. The analytic sample was comprised of geriatric patients 65+ years of age with an ICD-9 code corresponding to CHF. RESULTS: There were no statistically significant differences between earlier hospital readmission versus later/non-readmitted sample patients when grouped by age, race, gender or level of measured social isolation. However, composite comorbidity scores were significantly lower for patients in the >30-day/non-readmitted subgroup compared to earlier readmission patients. CONCLUSIONS: These initial study results suggest that a larger proportion of CHF hospital readmissions may be more heavily influenced by clinical factors than social living arrangements. Future studies with larger samples and validated measures of social isolation are needed to inform the development and testing of programs for geriatric CHF patients striving to avoid unnecessary hospital readmissions and adverse health outcomes. Keywords: social isolation, congestive heart failure, comorbidity, geriatric medicine
INTRODUCTION

The geriatric population in the U.S. is rapidly growing.\(^1\) Geriatric patients who are 65 years and older tend to be particularly concentrated users of the health care system.\(^2\) This group of patients also have higher relative rates of hospital admissions and readmissions for congestive heart failure (CHF).\(^3\) In addition to the monetary burden placed on patients and hospitals, readmissions also often severely disrupt the well-being of CHF patients and families. A growing number of U.S. healthcare systems are beginning to brace for increased numbers of geriatric patients as a result of an aging “baby boomer” generation.\(^4\)

During recent years, the Center for Medicare and Medicaid Services (CMS) has focused attention on higher-cost users of health care systems. An important example of this phenomenon concerns how admissions and readmissions for the diagnostic related group (DRG) amount of CHF is routinely associated with especially high healthcare costs. This chronic condition alone accounts for 6.5 million annual hospitalizations in geriatric patients and directly/indirectly accounts for 60-70% of their hospital admissions.\(^5\) Medicare now penalizes hospitals for excessive 30-day readmissions for CHF.\(^6\)

For years, the CHF 30-day hospital readmission rate has been used as a key quality of care measure by CMS and served as a research focus.\(^3\) The cost of CHF readmissions has been estimated at $28 billion per year, with annual costs increasing significantly to $44 billion dollars for all-cause readmissions of CHF patients.\(^5\) In addition, it has been estimated that 75% of all-cause readmissions could be avoided, comprising an annual potential savings of $12 billion.\(^6\)

In 2010, the Patient Protection and Affordable Care Act was signed into law containing measures to penalize hospitals for all-cause readmissions within 30 days of discharge.\(^6\) Therefore, a major goal for hospitals is to develop improved strategies to reduce readmission rates and avoid financial penalties. Due to the multiple complex influences frequently affecting many CHF outcomes, investigators need to continue to examine potential risk factors of CHF readmissions.\(^3\)

One particular risk factor, “social isolation,” is a term typically used to refer to a physical separation from other people (e.g., living alone) and/or residing in a rural geographic area.\(^7\) Social isolation has also been more broadly defined as having few...
social ties that one can rely on for practical and emotional support. Age, gender, marital status, and socio-economic status may also play an influential role on perceived social isolation levels among the geriatric population.

The increased prevalence of social isolation has already been well characterized in older adult populations. It has also been demonstrated that social isolation is more common in women than men, especially those who are widowed. Additionally, studies have shown that geriatric patients who experience social isolation are more likely to develop severe comorbidities including cognitive decline, infectious disease and cardiovascular disease. This could be a result of or a combination involving increased self-neglect or less access to health care, although the exact relationship remains to be more fully defined.

Even though there is substantial evidence that social isolation is associated with a worse prognosis after acute myocardial infarction, there is still little evidence concerning the potential influence of social isolation on prognoses for CHF. Since a growing number of geriatric persons tend to possess more comorbidities with increased social isolation, our nation has an urgent need to better understand the health care usage patterns of socially isolated geriatric patients.

New “specialized” emergency departments (ED) focusing on the needs of geriatric patients are becoming increasingly common in the US. These types of ED focus on the needs of geriatric patients with respect to symptomatic relief and systematic screening for more prevalent clinical comorbidities and social factors. When such screening assessments indicate unmet needs, ED professionals facilitate contact with social workers to connect geriatric patients with specific services. One factor that some new EDs screen geriatric patients for is “social connectedness,” asking questions to assess the support networks that individual patients currently feel they have.

Purpose of Study
The primary purpose of this study was to identify the relationship between social isolation levels and “earlier” (i.e., less than 30-day post-discharge) and “later” (i.e., 30 days or later) hospital readmission rates in a convenience sample of geriatric CHF patients. The authors utilized a series of questions that had already been included in the electronic health record during geriatric patient screening in the authors’ specialized ED.
In addition, the authors examined the relative predictive significance of composite comorbidity levels using the Charlson Comorbidity Index (CCI) method.13

**Setting**

The study was conducted at a single setting which was a Southeastern Michigan 304-bed community hospital ED with 45,000 annual visits. In 2012, setting ED patients were 69% White, 26% Black, 1% Asian, and 4% all other races. In August, 2010, a specialized geriatric ED opened at this site. During 2012, this specialized ED accommodated approximately 5,000 (19%) of all system ED patients. Two additional hospitals with ED were located within 20 miles of this study hospital. Before the study, senior ED staff members had received earlier geriatric health care training comprised of a web-based curriculum, and the entire ED facility had undergone redesign to accommodate the new geriatric ED. One section of the ED was designated as the “Senior ED” although any patients who were \( \geq 65 \) years of age received the same screening.

**METHODS**

The authors examined the CHF hospital readmission rates among sample geriatric patients with varied levels of social isolation based on a non-validated four-point scale used in the electronic health record at the authors’ specialized ED.13 Criteria to stratify patients into social isolation levels were determined by the following three screening questions in the nursing assessment and screening module: 1. “Currently unmarried,” 2. “Lives alone,” and 3. “Lacks caregiver.” Each answer was scored with one point.

For example, a patient who was married, lived with one or more others, and had a caregiver would receive a score of “0.” Hence, a lower score was interpreted as indicating a lower level of social isolation. The points from screening items were added, allowing classification of sample patients along a four-point integer scale. A score of 2 to 3 was used to define patients as socially isolated individuals. A score of 0 to 1 represented non-socially isolated individuals.

Before the study, the authors had hypothesized that CHF patients who were readmitted into the study hospital within 30 days would have overall lower social isolation scores than CHF patients possibly returning to the facility greater than 30 days after discharge. The secondary outcome of the study was to determine whether composite CCI
scores would have a significant influence on predicting 30-day hospital readmission events in sample patients.

The authors conducted a retrospective chart review of geriatric patients who were first admitted to the hospital with a DRG code of CHF and stratified grouped according to their history of hospital readmission (if any). These two categories included: a) those patients who were readmitted within 30 days, and b) those who were not readmitted or readmitted after more than 30-days (Fig. 1). This stratification parameter was largely derived from the 30-day hospital readmission CMS penalties already described in this paper.

The electronic health records of geriatric CHF patients admitted during a six-month period from September 1, 2013 through February 28, 2014 were reviewed. The early hospital readmission group consisted of 94 patients readmitted with a diagnosis of CHF. The remainder of the analytic sample consisted of 192 geriatric CHF patients who were never readmitted during the six-month study window, or readmitted after greater than 30 days. The authors had already scored each patient for social isolation levels and other comorbid conditions using their data abstraction tool. Chart auditors were blinded to data concerning any possible hospital readmission events.

Patients’ composite comorbidity levels were classified using the CCI method. Although other methods exist, this method is a long-validated instrument classifying comorbidities that was first empirically developed using one-month mortality outcomes in a cohort of 604 hospital patients. The CCI classifies a patient based on their documented comorbid conditions such as diabetes, hypertension, and ischemic heart disease. Each condition is assigned a weighted score of between one through six depending on the influence of each condition on an individual’s prospective mortality risks.

Individual scores are then added together to generate a composite CCI score. By classifying comorbidities using this method, researchers are provided a validated technique of estimating the risk of mortality from comorbid diseases. Prior studies have demonstrated a correlation between higher CCI and other comorbidity score methods and increased readmission rates for heart failure.
Data Collection and Management Procedures

All study data were collected from the Cerner® electronic health record system of St. Mary Mercy Hospital in Livonia, MI. The following variables were extracted from sample patients’ charts:

- Socio-demographic characteristics - age, gender and race
- Admission dates
- Confirmation of documented diagnosis of CHF
- Data concerning current living conditions (e.g., married, living alone, etc.)
- Other comorbid conditions (diseases listed in CCI method)

Items used to determine sample patients’ social isolation levels were obtained from the electronic health record “Senior Triage Risk Screening Tool” module, and marital status was obtained from the “Patient Demographics” health record screen.

The principal investigator (author DK) trained each of three chart abstractors in the proper data abstraction technique. A three-page data dictionary was created for chart abstractors’ reference and the PI remained available to address their questions. Each patient was then assigned a unique identifier accession number.

Two trained medical residents helped interpret more complex data concerning abstracted comorbid conditions. The first 20 records were abstracted with generated spreadsheets compared to identify any discrepancies for possible abstractor retraining. Double data entry was instituted throughout the study to help ensure accuracy of data collection.

Statistical Considerations

Chart audit data were first transferred to an electronic spreadsheet and cleaned for statistical analysis. All statistical analyses were conducted using SAS, version 9.3.15 Inferential tests for significance of equality of two proportions of sample patient group hospital readmissions were carried out using the two tail Fisher’s exact test using GraphPad Software.16 Student’s t-test was used for comparing mean differences of continuous variables. A two-tailed coefficient Alpha p value of < 0.05 was observed to designate statistical significance.

The fifth author (SY) completed a series of multivariate logistic analyses to identify predictors and factors influencing readmission outcomes controlling for CCI and social
isolation scores. Final stepwise methods (i.e., one model term introduced at a time) logistic regression modeling procedures were initially completed. Due to the atypical nature of this geriatric CHF patient sample, this type of “non-parametric” analytic procedure was appropriate since it was not based on any “normal” distributional assumptions. The dichotomous dependent variable was “readmission” or “later/no readmission” as defined by the 30-day cutoff.

RESULTS

Chart data from a total of 286 geriatric CHF patients were included in the analytic sample, including 94 (32.9%) patients who were readmitted within 30 days after hospital readmission and 192 (67.1%) non-admitted or later-readmission patients (Figure 1).

Based on initial modeling results in which factors such as age, gender and race were found to be non-significant predictors, only the CCI score and social isolation score were used as independent variables in the final models. As depicted in Table 1, primary potential study influences such as age, race and gender demonstrated no statistically significant differences on readmission group differences (Table 1).

The influence of CCI comorbidity scores, however, were significantly lower for the later readmission (i.e. listed as “RL”) subgroup (OR 0.83; 95%CI 0.75 - 0.93). However, there was no significant difference found between sub groups stratified by total isolation scores (OR 0.97; 95% CI 0.71 - 1.40) (Fig. 2 and Table 2). Neither did individual social isolation questions show significant differences: 1. No caregiver (OR 0.73; 95% CI 0.18 - 3.06), 2. Patient lives alone (OR 0.86; 95% CI 0.45 - 1.64), and 3. No current partner (OR 1.17; 95% CI 0.65 - 1.87) (Table 3).

DISCUSSION

This study examined the potential impact of social isolation on hospital readmissions in geriatric CHF patients initially screened in a specialized ED. The social isolation measure used during the study had been developed from available pre-existing screening questions used in this ED at the time of the study. No significant associations were found between social isolation scores and CHF ≤30-day hospital subgroup readmissions (primary outcome). Individual selected socio-demographic study measures
also failed to demonstrate statistical significance.

**Study Limitations**

The authors’ specific measure to evaluate social isolation levels in sample patients had not been previously validated. The use of externally validated social isolation screening tools may have required a more complex project design.

Other validated social isolation research tools certainly do exist.\textsuperscript{14,15} To that end, the authors are currently designing a prospective study to obtain more comprehensive screening profiles using a validated screening tool. Another challenge encountered during this current study was the limited sample size. This factor may not have provided the authors with an adequate level of statistical power to detect significant sample subgroup differences in hypothesized relationships.

It is also possible that patients who had been initially treated at the authors’ hospital were subsequently seen and readmitted at another hospital, preventing them from being counted as readmissions. However, it is quite unlikely that sample patients would have been admitted to another hospital facility given that their provider, prior testing results, and medical records were at this hospital. However, there is still no precise way of gauging what the actual magnitude of this potential issue could have been.

One key characteristic of a specialized senior ED is the systematic use of screening tools.\textsuperscript{12,17} Such screening includes a variety of tests for common comorbid conditions of geriatric patients. In this study, we did demonstrate that the CCI comorbidity scores were significant predictors of readmissions for sample patients, although this was not the primary outcome of the study. Other studies have demonstrated benefit from implementation of a “case management” approach to higher readmission populations during which individuals are identified and specific interventions applied.\textsuperscript{16,17} These geriatric patients typically receive systematic reviews of their medication use, and earlier follow up with their respective primary care physician or other subspecialist.\textsuperscript{17,18} Providers who implement such interventions may help to prevent more frequent ED visits and early hospital readmissions for CHF patients by improving their overall quality of life.\textsuperscript{17}
CONCLUSIONS

Based on these initial study results, the influence of social isolation levels on hospital readmission rates among geriatric CHF patients may be less than that from overall comorbidity. Patients with higher CCI comorbidity levels were, significantly more likely to be readmitted to the hospital within 30 days. Future studies with larger samples and validated social isolation measures are needed to inform the development and testing of programs assisting geriatric CHF patients avoid unnecessary hospital readmissions and related adverse health outcomes.

The authors report no external funding source for this study.

The authors declare no conflict of interest.

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ACKNOWLEDGEMENTS

1. The authors would like to thank Chandra Lake, BS who assisted with IRB submission.
REFERENCES
6. Thompson MP, Waters TM, Kaplan CM, Cao Y, Bazzoli GJ. Most hospitals received annual penalties for excess readmissions, but some fared better than others. *Health Aff*. 2017;36(5):893-901.
Influence of Isolation and Medical Comorbidities on Geriatric CHF Readmissions

TABLES AND FIGURES

Figure 1:
Hospital Readmission Patterns of Sample Patients

Admitted from ED with CHF in specified time frame
n= 286

Returned early
n = 94

Returned late
n = 192

Excluded:
Did not report one or more key elements of social isolation
n= 21

Social isolation Present
n = 53

Social isolation Absent
n = 212
Figure 2:
Distribution of CHF Patients by Social Isolation Scores and < 30-day Readmission (RE) and Later/non-readmitted (RL) Outcomes (N = 286)
Table 1:  
CHF Sample Patient Characteristics and Readmission Outcomes (N = 286)

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Early Readmissions (N=94)</th>
<th>Late and Non-Readmissions (N=192)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Mean 83.3</td>
<td>82.4</td>
<td>0.4700</td>
</tr>
<tr>
<td>CCI Score</td>
<td>5.13</td>
<td>4.19</td>
<td>0.0009</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td>0.2108</td>
</tr>
<tr>
<td>Females</td>
<td>52 (55.3%)</td>
<td>121 (63.0%)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>42 (44.7)</td>
<td>71 (37.0)</td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td>0.4739</td>
</tr>
<tr>
<td>White</td>
<td>88 (93.6)</td>
<td>172 (90.0)</td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>6 (6.4)</td>
<td>19 (9.9)</td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>0 (0.0)</td>
<td>1 (0.52)</td>
<td></td>
</tr>
</tbody>
</table>

P-values are the result of either two-tailed student’s t-test or chi-squared analyses.  
**Bold** p value is statistically significant.
### Table 2:
**Distribution of Social Isolation Characteristics and Readmission Outcomes**
(N = 286)

<table>
<thead>
<tr>
<th></th>
<th>Early Readmissions (N=94)</th>
<th>Late and Non-Readmissions (N=192)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lacks Caregiver</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18 (20.9)</td>
<td>6 (3.4)</td>
<td>0.9136</td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18 (20.9)</td>
<td>6 (3.4)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>68 (79.1)</td>
<td>173 (97.1)</td>
<td></td>
</tr>
<tr>
<td><strong>Lives Alone</strong></td>
<td></td>
<td></td>
<td>0.7930</td>
</tr>
<tr>
<td>Yes</td>
<td>18 (21.0)</td>
<td>35 (19.6)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>68 (79.1)</td>
<td>144 (80.4)</td>
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</tr>
<tr>
<td><strong>Marital Status</strong></td>
<td></td>
<td></td>
<td>0.8133</td>
</tr>
<tr>
<td>Married</td>
<td>34 (36.2)</td>
<td>64 (33.3)</td>
<td></td>
</tr>
<tr>
<td>Single/Widowed/Divorced</td>
<td>60 (63.8)</td>
<td>128 (66.7)</td>
<td></td>
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</table>

P-values are the result of two-tailed Student’s t tests.

### Table 3:
**Social Isolation Logistic Regression Analyses of Readmissions controlling for Comorbidity Scores**

<table>
<thead>
<tr>
<th></th>
<th>Number of patients used in analyses</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient Lacks Caregiver</strong></td>
<td>262</td>
<td>0.73</td>
<td>0.18-3.06</td>
</tr>
<tr>
<td><strong>Patient Lives Alone</strong></td>
<td>265</td>
<td>0.86</td>
<td>0.45-1.64</td>
</tr>
<tr>
<td><strong>No Current Partner</strong></td>
<td>286</td>
<td>1.107</td>
<td>0.65-1.87</td>
</tr>
<tr>
<td><strong>Social Isolation Score of Earlier Readmission vs. Later/non-readmission Patients</strong></td>
<td>286</td>
<td>0.996</td>
<td>0.71-1.40</td>
</tr>
</tbody>
</table>
The Use of Magnetic Resonance Cholangiopancreatography (MRCP) in the Setting of Acute Pancreatitis: When is it Most Useful?

Karlin Sevensma DO, FACOS,1 Miranda Allen DO,2 Rebecca Harden DO,2 William Corser PhD 3

1 Metro Health General Surgery Program Director, Wyoming, MI.
2 Metro Health General Surgery Residency Program, PGY 2, Wyoming, MI.
3 Statewide Campus System, MSU College of Osteopathic Medicine, East Lansing, MI.

Corresponding Author: Karlin Sevensma DO, FACOS, ksevensma@sbcglobal.net

ABSTRACT

SEVENSMA K, ALLEN M, HARDEN R, CORSER W. The Use of Magnetic Resonance Cholangiopancreatography (MRCP) in the Setting of Acute Pancreatitis: When is it Most Useful? Spartan Med. Res. J. Vol. 2, No.1, pp. 30-42, 2017. CONTEXT: The usefulness of MRCP in the workup of acute pancreatitis has long been debated. METHODS: 2013-2016 chart review data were collected by the authors from adult patients with acute pancreatitis who also had received Magnetic Resonance Cholangiopancreatography (MRCP). Those patients were categorized by diagnosis and according to whether or not the MRCP changed healthcare services. RESULTS: Changes in care were significantly correlated with diagnosis and elevated liver function tests (LFT). The patients who benefitted most from MRCP were those with acute gallstone pancreatitis (r = 0.298, n = 109, p = 0.002) and patients with elevated LFT (r = 0.219, n = 89, p= 0.040). The most common way that MRCP influenced the care of patients with acute gallstone pancreatitis was by allowing providers to forego intraoperative cholangiogram (IOC) when MRCP results were negative (r = 0.335, n = 109, p < 0.001). CONCLUSIONS: The authors conclude that this was not the most cost effective management practice since the cost of intraoperative cholangiogram was about one quarter that of MRCP. Limiting MRCP use in patients with acute gallstone pancreatitis and preferentially using IOC at the time of surgery can likely decrease hospital costs without compromising care. Keywords: acute pancreatitis, cholangiography, cholangiopancreatography, elevated LFT

INTRODUCTION

Magnetic resonance cholangiopancreatography (MRCP) is an expensive study, averaging over $2,000.1 Although MRCP has long been thought to be a reliable predictor of choledocholithiasis, patient selection criteria for MRCP could potentially be refined to improve its cost-effective use. During the past 10 years, MRCP has been increasingly utilized in the evaluation of bile duct pathology, more frequently shifting the care of patients with acute gallstone pancreatitis to pre-operative biliary duct evaluation.1 As
intraoperative cholangiogram (IOC) and endoscopic retrograde cholangiopancreatography (ERCP) are now less often ordered, the management of common bile duct stones has been found to be more often affected by the availability of instrumentation, personnel and skills rather than cost-effectiveness.2

Numerous studies have shown MRCP to be nearly as accurate as ERCP for detecting common bile duct pathology.2,3,10 In the authors’ institution, MRCP is one of the first studies performed on patients admitted with presumed choledocholithiasis or acute gallstone pancreatitis. However, recent studies have called into question the routine use of MRCP in these patients, especially given that many patients with acute gallstone pancreatitis do not have choledocholithiasis at time of presentation.5 Cavdar et al. demonstrated that delayed MRCP at seven days after the onset of symptoms was more accurate than on admission.5 This study group also recommended that MRCP in acute biliary pancreatitis should be withheld for at least a week if there is no clinical worsening since many patients with choledocholithiasis will spontaneously pass their stones.5 Lin et al. determined that laparoscopic cholecystectomy and IOC were associated with a shorter length of stay than preoperative MRCP or ERCP in patients with suspected choledocholithiasis.4

Richard et al. found that MRCP had a high rate of false normal results (Negative Predictive Validity 77%) compared with IOC and is not as accurate as more invasive diagnostic techniques.6 This group concluded that there was no need for pre-operative MRCP in patients with suspected choledocholithiasis, and that cholecystectomy with IOC was preferred.6 Although one study also concluded that liver function tests (LFT) are not predictive of CBD pathology on MRCP,7 the results from other studies have shown them to be somewhat predictive.8,12

**Purpose of Study**

This study was conducted to examine the use of MRCP and its effectiveness in altering care in a sample of hospital patients with different types of acute pancreatitis, specifically gallstone and acute pancreatitis from other causes, such as alcohol, hyperlipidemia, drug-induced and idiopathic. This study also examined whether LFT on admission or hospital Day One were predictive of MRCP revealing biliary duct pathology. Before the study, the authors hypothesized that MRCP was potentially being over-utilized
and might offer limited benefit to only certain types of patients. The authors anticipated that this could save hospital costs if those patients could be identified and workup re-directed.

METHODS

This study was reviewed and approved by the Metro Health Hospital Institutional Review Board. A waiver of informed consent was received. Following this approval, retrospective chart reviews were completed by the first three authors for all adults admitted to the hospital between January 2013 and May 2016 with a diagnosis of “acute pancreatitis” at any time during their hospital stays. Information regarding their admitting provider, date of admission, date of discharge, date of MRCP, findings of MRCP, interpreting radiologist, liver function tests, ultrasound findings, date of laparoscopic cholecystectomy, intraoperative cholangiogram and findings, date of ERCP and findings, and type of acute pancreatitis were also collected.

The following inclusion and exclusion criteria were observed:

Inclusion Criteria:

• Patients 18 years of age and older
• Admitted to the hospital and diagnosed with acute pancreatitis between January of 2013 and May of 2016
• Underwent MRCP for evaluation

Exclusion Criteria:

• Patients under 18 years of age
• Diagnosis of chronic pancreatitis

MRCP results were then classified as “positive” if there was visible pathology causing bile duct obstruction (e.g., stone, sludge, mass or stricture.) For other cases in which there was no visible cause of duct obstruction, results were classified as “negative.” Bilirubin and transaminases LFT values were categorized as “normal” or “elevated” for analyses based upon standard normal ranges for the hospital laboratory. Finally, whether each sample patients’ care had changed based upon MRCP result was determined. A change in care was defined as follows. For patients with acute gallstone pancreatitis, a change in care was considered to have occurred if the patient had preoperative ERCP,
an ERCP ordered instead of surgery or if no IOC was performed at the time of surgery since the MRCP was negative. For patients with other types of acute pancreatitis, an MRCP was considered to have changed care if an ERCP was ordered as a result of the MRCP results.

**Statistical Analysis**

After data cleaning, a series of descriptive statistics (frequencies, cross-tabulation charts) Pearson product-moment bivariate correlational procedures were first completed to examine for both missing data patterns and study data distributional patterns of key variables. A basic two-tailed stepwise binary logistic regression predictive modeling procedure was then completed to examine for statistically significant influences on whether sample MRCP patients’ care was changed as a result of having received an MRCP. A coefficient Alpha two-tailed significance p value level of 0.05 was observed. All analyses were completed using S.P.S.S. version 22 analytic software. Statistical analysis was performed by the fourth author.

**RESULTS**

Four hundred and twelve patient encounters for acute pancreatitis were initially identified for analysis. A total analytic sample of 109 patients (26.5% of total population) from the initial data set had received MRCP as part of their workup for acute pancreatitis. This subgroup of patients was evaluated for: a) correlation of the MRCP result with elevation in transaminases and bilirubin LFT values, both on admission and hospital Day One, and b) how MRCP results may have changed their patient care.

Of the 109 patients undergoing an MRCP, 52 (47.7% of analytic sample) were found to have acute gallstone pancreatitis, with 57 (52.2%) diagnosed with acute pancreatitis of another type. Of the patients with acute gallstone pancreatitis, four (7.7%) patients had received a pre-operative ERCP as a result of the MRCP being positive for stone or sludge. Twenty-five (48.1%) of acute gallstone pancreatitis patients had received no IOC at the time of surgery because their MRCP was negative. Five (9.6%) patients with acute gallstone pancreatitis had an ERCP ordered to evaluate duct abnormalities and did not have surgery. Two (4.0%) patients did not fit into any of the above groups and were categorized as “Other.” Sixteen (30.7%) patients with gallstone pancreatitis had no change in their care due to their MRCP results.
This finding indicates that the patient either did not have surgery during admission for gallstones (six patients) or had undergone an IOC during surgery despite a negative MRCP (ten patients). In one of those cases, the IOC was positive for a filling defect that cleared with glucagon. In those patients with non-gallstone acute pancreatitis, 52 (91.2% of analytic sample) patients did not have any change made in their care as their MRCPs were negative. An ERCP was ordered in the remaining five (8.8%) patients, constituting a change in care. (See Table 1)

Overall, these patients' MRCP results (i.e., negative or positive) were significantly correlated with: a) whether or not at least one LFT result was elevated at admission and/or Day One \( (r = 0.219, n = 89, p = 0.040) \), and b) whether or not a patient was diagnosed with acute gallstone pancreatitis \( (r = 0.298, n = 109, p = 0.002) \) (Figures 1 & 2). The documented MRCP results (i.e., either negative or positive) were also significantly correlated with whether or not the surgical care provided to that patient was altered \( (r = 0.335, n = 109, p < 0.001) \).

Finally, a stepwise binary logistic regression model, in which potential predictive terms are entered into the preliminary predictive model and retained or removed (if initial Alpha significance level was greater than 0.010) was completed. This type of predictive model is not based on any assumption of normal distributional patterns and requires a dichotomous (i.e. Yes/No) outcome. In the final predictive model, two terms “survived” as significant influences concerning whether sample patient’s care was adjusted: a) whether or not the patient had been diagnosed with acute gallstone pancreatitis (Wald chi square = 3.888, \( p < 0.001 \) with df = 1), and b) whether or not patient had at least one elevated LFT result during the first 48 hours of their hospital stay (Wald chi square = 3.888, \( p = 0.049 \), with df = 1).

In our institution, an MRCP costs $2,014 (USD). The cost of an IOC in this setting is somewhat less straightforward, varying on the amount of operative time used for IOC. If an additional operative time of 15 minutes is used for the calculation, an IOC at our institution costs $748 (USD), nearly a third the cost of MRCP. (See Table 2 for IOC cost calculation.)
DISCUSSION

Based on these results, the authors’ overall hypothesis that MRCP would offer limited benefit to certain types of acute pancreatitis patients was supported. The patients who showed the most benefit from having received an MRCP were those with acute gallstone pancreatitis and those with elevated LFT.

Since MRCP is a relatively expensive study, it should be reserved for patients who will more likely benefit from it. These study results indicate that patients with acute gallstone pancreatitis benefited more from MRCP than patients with other causes of acute pancreatitis. Unfortunately, much of this benefit was in the form of avoiding an IOC. The problem with using MRCP in this way is that the test has been demonstrated to have a high false negative rate in some studies.6,11

MRCP has not been shown to be as cost-effective as IOC for evaluating the duct for pathology, nor has it been shown to be as accurate.6,9 Pre-operative MRCP is more expensive than IOC and may also prolong hospital length of stay.6 In our study, using IOC preferentially to MRCP in patients with acute gallstone pancreatitis undergoing laparoscopic cholecystectomy would have decreased the need for an MRCP by about 25% of all cases. However, if a patient is not considered to be a candidate for laparoscopic cholecystectomy (e.g., in patients with other etiologies of acute pancreatitis), this approach is not as viable.4,6 When possible, IOC should be done preferentially to MRCP for the purposes of accuracy, cost-effectiveness, and efficiency. Based on these study findings, MRCP should not be ordered as a first line test in patients with acute pancreatitis not attributable to gallstones since it is unlikely to change care or affect management decisions.

As indicated in our data, patients with elevated transaminases and/or bilirubin LFT within 48 hours of admission were more likely to benefit from MRCP than those who did not have elevated lab values. This suggests that MRCP should generally be reserved for patients with elevated LFT and only ordered with reservation when LFT are normal.

This study’s scope was limited secondary to being a single-site, retrospective study. The conclusions drawn from this study should be further evaluated in larger multi-site prospective studies examining preferential use of IOC over MRCP in patients with acute gallstone pancreatitis. Furthermore, many of the acute pancreatitis patients in this
sample from causes other than gallstones did not undergo MRCP, perhaps obscuring the potential measured benefits of MRCP for those patients. Due to this smaller-sized convenience sample, the authors may have also lacked an adequate level of statistical power to detect other meaningful sample subgroup differences.

In this sample, MRCP was most useful in patients with acute gallstone pancreatitis, with the largest group of patients who benefited from MRCP being patients who had not undergone IOC at the time of laparoscopic cholecystectomy due to negative MRCP results. Due to the false negative rate of MRCP, using this test in this way is problematic. Since the majority of sample patients with gallstone pancreatitis did not have choledocholithiasis at the time of imaging or surgery, IOC may have been a more cost-effective way to rule out choledocholithiasis than MRCP. IOC can also be converted to a therapeutic procedure if the surgeon is trained in laparoscopic duct exploration and the necessary equipment is available. Selectively ordering an MRCP in patients with elevated LFT and performing an IOC during surgery in place of preoperative MRCP for acute gallstone pancreatitis patients will tend to decrease healthcare costs without compromising patient care.

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1. Special thanks to the Research Department staff at Metro Health Hospital, Maureen Oostendorp and Carmen Heaney for their project advice and ongoing support.
REFERENCES


# TABLES AND FIGURES

Table 1: Distribution of Patient Subgroups and Change in Care (N = 109 patients)

<table>
<thead>
<tr>
<th>Procedures ordered or not ordered based on MRCP result</th>
<th>N (% of category)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallstone pancreatitis N=52 (47.8% of total sample)</td>
<td></td>
</tr>
<tr>
<td>ERCP pre-op</td>
<td>4 (7.7%)</td>
</tr>
<tr>
<td>No IOC</td>
<td>25 (48.1%)</td>
</tr>
<tr>
<td>ERCP ordered</td>
<td>5 (9.6%)</td>
</tr>
<tr>
<td>other</td>
<td>2 (4.0%)</td>
</tr>
<tr>
<td>No change in care</td>
<td>16 (30.7%)</td>
</tr>
<tr>
<td>Non-gallstone pancreatitis N=57 (52.2% of total sample)</td>
<td></td>
</tr>
<tr>
<td>ERCP</td>
<td>5 (8.8%)</td>
</tr>
<tr>
<td>No change in care</td>
<td>52 (91.2%)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>109</strong></td>
</tr>
</tbody>
</table>
### Table 2: Calculation of Total Intraoperative Cholangiogram (IOC) Costs

<table>
<thead>
<tr>
<th>Component of cost</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surgeon Reimbursement</strong> (Medicare cost)</td>
<td>$58</td>
</tr>
<tr>
<td><strong>Radiologist Interpretation</strong> (Medicare)</td>
<td>$19</td>
</tr>
<tr>
<td><strong>Anesthesiologist Charges</strong> 15 minutes (Medicare)</td>
<td>$22</td>
</tr>
<tr>
<td><strong>Hospital Operating Room charges</strong> (15 minutes)</td>
<td>$263</td>
</tr>
<tr>
<td><strong>Fluoroscopy Charges</strong> (C-arm, contrast, technologist)</td>
<td>$264</td>
</tr>
<tr>
<td><strong>Supplies for IOC</strong> (catheter, syringes, connectors)</td>
<td>$122</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$748 (USD)</td>
</tr>
</tbody>
</table>
Figure 1: Relationship between MRCP Result and Potential Changes in Patient Care

Did MRCP Result in Change of Surgical Care Provided?
Figure 2:
Relationship Between Whether Patient was Diagnosed with Gallstones and Whether Change in Patient Care Resulted

Did MRCP Result in Change of Surgical Care Provided?

Were patient diagnosed with gallstone pancreatitis?

- NO
- YES
Case Series

Robot-Assisted Repair of Acquired Abdominal Intercostal Hernias (AIH)

Daniel Smith DO,¹ Mohan Kulkarni MD, FACS, FRCSC,² Shawn Obi DO, FACS ³

¹ Henry Ford Allegiance General Surgery Resident, PGY 5, Jackson, MI
² Henry Ford Allegiance Thoracic Surgeon, General Surgery Program Director, Jackson, MI
³ Henry Ford Allegiance General Surgeon, General Surgeon Teaching Facility, Jackson, MI

Corresponding Author: Daniel E. Smith DO, danielsmith@allegiancehealth.org

ABSTRACT

SMITH D, KULKARNI M, OBI, S. Robot-Assisted Repair of Acquired Abdominal Intercostal Hernia. Spartan Med. Res. J. Vol. 2, No.1, pp. 43-56, 2017. CONTEXT: Abdominal intercostal hernia (AIH) is a rare clinical entity in which intra-abdominal visceral contents protrude through a defect between adjacent ribs. Most AIH are repaired via (an open or a laparoscopic) transabdominal approach or a thoracotomy. METHODS: In this paper, the authors present two cases of AIH. RESULTS: Both cases of AIH developed in male patients after severe coughing episodes and demonstrated on computed tomography (CT) to include multiple abdominal viscera. In both cases, a robot-assisted laparoscopic hernia repair was performed utilizing Sepramesh and V-Lock suturing. To our knowledge, these are the first case reports of a robotic approach to repair of AIH. CONCLUSIONS: Both cases demonstrate the safety of this approach and expand on novel robotic approaches to ventral hernia repairs. Studies of longer term outcomes from this surgical approach are limited in the literature due to small number of cases and even fewer associated case reports. Keywords: intercostal hernia, robot, laparoscopic repair, case series

INTRODUCTION

Abdominal intercostal hernias (AIH) are a rare entity with varying numbers (i.e., between 10 to 29) cases reported in the surgical literature.¹,²,³,⁴,⁵,⁶,⁷ Intercostal hernias are appropriately categorized into acquired versus spontaneous with the presence (i.e., a trans-diaphragmatic intercostal hernia) or absence of diaphragmatic involvement.¹ This case series will report on two AIH cases that did not involve the patients' diaphragms.

Patients with AIH typically present with a symptomatic chest wall bulge in conjunction with a traumatic inciting event such as rib fracture, penetrating injury or previous surgery.¹ Occasionally, (as in the cases reported in this paper) AIH patients present after a severe coughing episode after which they have usually been symptomatic for weeks to months.⁸ Diagnosis is usually delayed due to a low index of provider
Robot Assisted Repair of Acquired Abdominal Intercostal Hernias

suspicion and failure to consider this entity in the differential diagnosis.\textsuperscript{1,2} In most cases, the AIH is formally diagnosed on a computed tomography (CT) scan of the chest and abdomen. Other diagnostic modalities include a thorough physical exam, laparoscopy, and ultrasound.

These types of hernias usually occur antero-laterally due to native weakness at the costochondral junction, a point occurring between the ribs and the costal cartilage in the front of the rib cage.\textsuperscript{9} Contents can include anything from within the peritoneal cavity with colon, liver, omentum, fat, and stomach all reported.\textsuperscript{1,2} The hernia contents are rarely incarcerated and even strangulated, in one documented case causing liver necrosis.\textsuperscript{2}

A variety of repairs have been described in the surgical literature including open trans-abdominal, thoracotomy, and laparoscopic repair.\textsuperscript{1} Usually these are repaired in a tension free fashion and covered with mesh.\textsuperscript{1} Although some experts have advocated for re-approximation of the involved ribs, this is rarely performed due to defect size and concerns of iatrogenic rib fractures and external deformity.\textsuperscript{1,2,3,6,9,10} The recurrence of AIH is high and can be managed surgically or followed conservatively depending on the clinical context.\textsuperscript{1,9} The authors had found no reports of robotic repairs of an AIH.

**Presentation of Cases**

Patient #1 was a Caucasian male in his mid-60’s with a history of chronic obstructive pulmonary disease (COPD), hypertension, and obesity (body mass index (BMI) of 30.43). Four months prior to evaluation, he experienced a severe coughing episode secondary to his COPD that resulted in severe right-sided chest wall pain, subsequent hematoma and contusion. Two months prior to the authors’ evaluation, the patient noticed a right antero-lateral chest wall bulge that gradually increased in size. This became increasingly symptomatic, causing him pain, nausea, and occasional emesis.

Patient #2 was a Caucasian male in his early-mid-70’s with a history of benign prostatic hypertrophy (BPH), gastro-esophageal reflux disease (GERD), obstructive sleep apnea (OSA), and obesity (BMI of 35.58). Eight months prior to evaluation, he suffered from a severe coughing episode related to an earlier hospital admission for pneumonia. The patient experienced a tearing sensation in his right anterior chest wall and gradually developed a bulge over the next few months. This bulge became increasingly
symptomatic with pain during movement and insomnia due to his inability to sleep on his side.

Patient #1 was initially diagnosed with a subcutaneous lipoma. Given the persistent nature, increasing size, and worsening symptoms from the bulge, a CT scan was performed to reveal a defect between anterior ribs 9-10 including cecum, ascending colon, and omental fat (Figure 1).

Patient #2 presented with a written report from an out of state chest CT stating the presence of an AIH. A repeat abdominopelvic CT that was performed for surgical planning revealed a similar defect to patient #1 in the right anterolateral chest wall. The hernia contents included portions of small bowel and a portion of the right colon (Figure 2).

Physical exams of both patients revealed obese males with protuberant abdomens. Lungs were bilaterally clear on auscultation with no evidence of increased work breathing. Cardiac auscultation revealed a regular rhythm with no murmurs. On both patients, right chest wall exams revealed a sizable bulge which was appropriately tender to palpation. There were no overlying cicatrices (scarring) to indicate previous trauma or surgery.

In a supine position, each of the patients’ bulges were fully reducible but immediately recurred with any patient movement. The intercostal defects were sizable on both patients with Patient #1 revealing a defect that measured approximately 6 x 11 cm. Patient #2 revealed a defect measuring approximately 11 x 13 cm. Both patients had otherwise normal abdominal examinations without features of incarceration or strangulation.

A robotic intercostal hernia repair was offered to both patients with an explanation of the possibility to convert to an open abdominal or thoracotomy approach as needed. Case #1 was performed by a thoracic surgeon and Case #2 performed by a general surgeon. Written surgical consents were obtained per protocol.

Patient #1: The patient was placed in supine position, airplaned to the left at 30 degrees, and placed in a reverse Trendelenburg position (body is flat while the head is elevated 15-30 degrees higher than the feet). A peri-umbilical Veress (situated or occurring adjacent to the navel) entry was made into the peritoneal cavity and the abdomen insufflated to 15 mmHg. A peri-umbilical 8 mm. robotic trochar was placed and
the abdomen inspected for any iatrogenic injuries and none were noted. Two additional 8 mm working ports were also placed, one in the right lower quadrant, and one in the epigastrium. A da Vinci surgical system Xi (Intuitive Surgical, Inc. Sunnyvale, CA) robot was then docked and the area inspected. The hernia contents were easily reduced and revealed no evidence of ischemia or perforation (Figure 3).

The intercostal defect was measured and a 7.6 x 13 cm. oval shaped Sepramesh (Bard Davol Inc. Providence RI) was brought onto the surgical field. Primary closure of the defect was not performed. The mesh was anchored in place at the antero-medial and posterolateral ends utilizing 2-0 Vicryl (Ethicon Inc, Somerville, NJ). The mesh was then affixed circumferentially utilizing a 2-0 V-lock (Medtronic, Fridley, MN) suture in a running fashion with a 2cm. overlap of normal tissue. The ribs were not incorporated in the suture (Figure 4).

The abdomen was then desufflated, the trocars removed, and the skin closed. The patient was admitted for observation, given a clear liquid diet on day of surgery, and pain controlled utilizing intravenous Tylenol and Hydromorphone. His foley catheter was discontinued upon arrival to the floor and he ambulated that day. The patient was discharged on the second post-operative day without any post-operative complications. He was doing well at his two-week post-operative office visit without pain or evidence of recurrent hernia. He did present six months postoperatively with complaints of swelling in his lateral abdominal wall. CT scan of the abdomen and pelvis revealed no evidence of AIH recurrence.

Patient #2: An open Hasson technique in the left upper quadrant was employed to gain intra-abdominal access. Three additional 8 mm working ports were placed, one in the left mid-abdomen, and one in each lower quadrant respectively. The patient was placed in reverse Trendelenburg and rotated to the left. The hernia contents were easily reduced into the peritoneal cavity. Primary closure was not performed. A 15 x 20 cm. Sepramesh was used to cover the defect and circumferentially sutured in place utilizing 2-0 V-Loc suture. The ribs or periosteum were not intentionally incorporated in the suture or mesh. Satisfactory coverage of the defect with approximately 2 cm. overlap of normal tissue was noted at the end of the case. The robot was undocked, pneumoperitoneum
(abnormal presence of air or other gas) evacuated, ports removed, and the dominant 12 mm port site fascia closed utilizing O Vicryl suture.

Postoperatively he was admitted for observation with a similar pain control regimen to patient #1. His post op course was complicated by post-operative urinary retention and a hospital readmission for a post-operative ileus (malfunonction in intestinal motility). These problems resolved with conservative management and supportive care. The patient was recovering well after his two-week readmission follow up appointment with no evidence of early hernia recurrence.

DISCUSSION

AIHs are an uncommon clinical entity with fewer than 30 cases reported in the literature.1,2,3,4,5,6 Our two cases are interesting for several reasons. One being that there are only three case reports of a laparoscopic approach to repair this clinical entity. Our cases also appear to be the first reported repairs of an AIH utilizing robotic technology. These patients had no previous history of traumatic inciting event other than their severe coughing episodes. Despite this, both patients’ hernias were quite large containing multiple abdominal viscera.

Additionally, we utilized a V-lock suture to fixate the mesh – a facile technique using robotic technology. In both cases, we elected to not perform primary closures given the chronicity and size of the defects and low likelihood of patient benefit. In addition, primary closures may have potentially subjected these patients to unnecessary rib fractures, chronic pain from intercostal nerve entrapment, and an unsatisfactory cosmetic appearance.

To our knowledge, there are only three reports describing laparoscopic repairs of AIH defects.3,6,10 This is likely due to the unique and rare nature of AIH in conjunction with no standardized surgical approach. Two cases described covering the defect with an absorbable mesh with fixation using a laparoscopic tacker.3,6 The remaining case involved closure of the defect utilizing a percutaneous technique followed by laparoscopic placement and fixation of the mesh using a laparoscopic tacker.10 None of these three cases reported recurrence or complications on short term follow up. It remains unclear
whether there is any benefit derived from primary closure of the defect prior to mesh placement for AIH.\textsuperscript{2}

In 2009, a robot-assisted ventral hernia repair was first performed on a human and has been gradually gaining acceptance in the general surgery community.\textsuperscript{11,12,13,14} The primary purported benefit over a laparoscopic approach is the surgeon’s ability to close the fascia and use suture to fixate the mesh instead of laparoscopic tacks or transfascial stay sutures.\textsuperscript{13} Since there are no apparent case reports of a robotic approach to AIH repair, the overall efficacy and safety of the procedure remain undetermined. Advantages of the robotic approach include increased visualization, improved instrument dexterity, and decreased operator fatigue. Associated disadvantages include a significant capital investment, increased procedure costs, and need for specially trained support staff.

There have been several case reports of AIH from specific inciting events including trauma, rib fracture, and previous surgery.\textsuperscript{1,2,3,9,10} Additionally, there have been case reports describing AIH after an episode of severe coughing.\textsuperscript{6,7} This was presumably the cause of these two patients' hernias. The sizes of both hernias were surprising large given the relatively benign inciting event. Before surgery, both these patients had suffered significantly from their hernias (e.g., primarily pain and insomnia resulting from side sleeping habits). This factor highlights the importance of a durable repair to decrease subsequent patient morbidity.

An additional advantage demonstrated in our robot-assisted cases is that the mesh could be affixed utilizing a running barbed suture, a technique which is more difficult with standard laparoscopy.\textsuperscript{16,17} Although technically possible with standard laparoscopy, intracorporeal suturing is easier to master and more efficient due to the robotic wristed instruments.\textsuperscript{18} To our knowledge, no longer-term or prospective studies have been conducted on robotic ventral hernia repairs, making it unclear whether there is a benefit derived from using continuous sutures in place of laparoscopic tacks. It is our opinion that continuous sutures offer a more consistent approximation of the mesh to the abdominal wall, making it less likely for intra-abdominal contents to invade the pre-mesh space leading to a possible recurrence.

Although primary closures of hernia defects are routinely performed in robotic ventral hernia repairs, there are substantial differences between the anterior abdominal
wall and the lateral chest wall. Our patients both suffered from their AIH for approximately six and eight months respectively, making their tissues less favorable to re-approximation. The authors concluded that both patients were at high risk for iatrogenic rib fracture or chronic pain from intercostal neuralgia if a primary closure of the defect was attempted. The external cosmetic results of primary closure were also unpredictable and were an additional reason it was not attempted. This decision coincides with several case reports describing a similar clinical outcome.1,2,6

It has been our practice to use Sepramesh during ventral hernia repairs due to its durability and presence of a temporary hydrogel coating on the peritoneal surface. It is our experience that the hydrogel coating decreases the likelihood of adhesions forming to the repair and causing subsequent complications. Additionally, these were both two elective cases without contamination which allowed placement of the synthetic mesh.

Ultimately, the significant contribution to the surgical community from these cases is demonstration of successful and safe AIH repair utilizing robotic technology. The approach we utilized was derived from our robot-assisted ventral hernia repair experiences. Apart from the post-operative ileus and post-operative urinary retention in Patient #2, these patients ultimately did well and benefitted significantly. The longer-term durability and safety of this surgical approach remains to be more fully elucidated in future works.

CONCLUSIONS

AIH defects are a distinct clinical entity that can be addressed in a variety of surgical approaches. To date, a variety of open surgical techniques as well as three laparoscopic techniques have been described in the literature. We are not aware of any case reports describing a robotic approach. Robotic technology is becoming increasingly common across surgical specialties and there is an increasing need for description of novel approaches. Several points specific to our cases are worthy of further discussion and can potentially be improved upon.

The defect was not primarily closed in our cases so the durability of our repairs remains unclear. Although the benefit of running suture over tacks is speculative, our experiences indicate that this practice results in better mesh apposition. The choice of
mesh was also based on our experience and comfort level. In this case series, we have described a robotic approach to repairing AIH utilizing non-absorbable mesh with a running barbed suture that appears to hold promise for future clinical applications.

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The authors declare no conflict of interest.
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TABLES AND FIGURES

Figure 1:
CT Scan of Patient #1 Highlighting Defect Between Anterior Ribs 9-10 and Cecum, Ascending Colon, and Omental Fat
Figure 2:
CT Scan of Patient #2 Showing a Similar Defect to Patient #1 in the Right Anterolateral Chest Wall Including Portions of Small Bowel and Portion of Right Colon
Figure 3:
Patient #1 Hernia Contents Reduced Without Evidence of Ischemia or Perforation
Figure 4:
Patient #1: Mesh Affixed Circumferentially Utilizing 2-0 V-lock Suture with 2 cm. Overlap of Normal Tissue.
A Fatal Case of Neuroinvasive West Nile Virus Infection in an Immunocompromised Host

Justin Allen DO,1 Jennifer Conard DO,2 Michael Wang MD 3

1 Lakeland Health Internal Medicine Resident, PGY 3, Saint Joseph, MI
2 Lakeland Health Internal Medicine Resident, PGY 3, Saint Joseph, MI
3 Lakeland Health IM Residency Program Director and Attending Physician Infectious Diseases, Saint Joseph, MI

Corresponding Author: Jennifer Conard DO, jenniferlconard@yahoo.com

ABSTRACT

ALLEN J, CONARD J, WANG M. A Fatal Case of Neuroinvasive West Nile Virus Infection in an Immunocompromised Host. Spartan Med. Res. J. Vol. 2, No. 1, pp 57-63, 2017. CONTEXT: The neuroinvasive form of West Nile disease is an uncommon manifestation of the viral infection. To date, documented cases in Michigan of neuroinvasive decompensation from this virus have been rare. Evaluation requires a broad differential diagnosis and treatment options are still quite limited. Objective evaluations entailing physical exam and radiographic and laboratory changes are nonspecific. Serologic testing of cerebrospinal fluid by enzyme immunoassay remains the gold standard for diagnosis. However, IgM antibodies typically do not develop until after the fourth to seventh day of symptom onset. METHODS: This retrospective case report presents an immunocompromised male patient in his mid-70s in whom neuroinvasive West Nile virus was diagnosed postmortem. All information was obtained from the patient's electronic health record. RESULTS: This patient's immunocompromised state at the time of West Nile exposure made him more susceptible to neuroinvasive disease progression and ultimately influenced the outcome. Prior to withdrawing care, the patient was treated for methicillin sensitive staphylococcus aureus (MSSA) cellulitis and Type 1 Herpes Simplex virus. CONCLUSIONS: In this case, neuroinvasive West Nile virus was a less likely diagnosis given the patient's physical exam findings and the context of more likely alternative explanations for his cognitive decline. Treatment options for neuroinvasive forms of West Nile virus are still supportive and would not have altered the patient's hospital course. This case report demonstrates that clinicians must maintain an ongoing index of suspicion for infection in warmer climates where West Nile is becoming more prevalent. Given some patients' obscure physical exam findings and radiographic imaging results, a thorough history with laboratory conformation is required for a more conclusive diagnosis. Keywords: West Nile encephalitis, immunocompromised host, neuroinvasive disease

INTRODUCTION

West Nile virus (WNV) typically presents as an asymptomatic febrile illness. In 1% of patients, WNV can progress to aseptic meningitis, encephalitis or poliomyelitis syndrome.1 The virus is transmitted to humans following a bite from an infected mosquito
that acquires the pathogen after feeding on a host, typically a bird. Person-to-person transmissions have also been observed following transfusion of blood products, organ transplantation, in hemodialysis patients, and through intrauterine, percutaneous, respiratory aerosol or breastfeeding exposure. Patients with hematologic malignancies are also at an increased risk for the neuroinvasive form of West Nile disease and have a poorer prognosis.

Serologic testing of cerebrospinal fluid (CSF) by enzyme immunoassay remains the gold standard for WNV diagnosis. IgM antibodies typically develop by the fourth to seventh day after onset of symptoms. Detection of WNV IgM in CSF is diagnostic of neuroinvasive disease. Since WNV IgM antibodies do not passively diffuse across the blood-brain barrier, CSF containing WNV IgM is needed to confirm intrathecal (spinal canal) penetration. Diagnosis can also be confirmed by WNV plaque reduction neutralization assay laboratory test (PRNT). WNV IgM antibodies, detected through enzyme-linked immunosorbent assay (ELISA), may persist after infection for twelve to sixteen months in the serum and seven months in the CSF.

In immunosuppressed patients, polymerase chain reaction (PCR) testing has a higher sensitivity than either PRNT or ELISA assay tests because these patient’s may not have yet mounted sufficient antibodies to the virus. The incidence of MRI abnormalities is variable and pathologic findings in WNV encephalitis, such as hyperintensity or signal changes on magnetic resonance imaging (MRI), are nonspecific.

**Case Report**

This patient was a male in his mid-70’s with a contributing past medical history of colon cancer status-post resection and colostomy, basal cell carcinoma, Lyme disease treated with doxycycline and chronic lymphocytic leukemia (CLL). His CLL had been diagnosed four years before and he was currently treated with chlorambucil, rituximab, and bendamustine. Following a chemotherapy holiday, he had been started on ibrutinib three months prior to presentation. In September 2016, the patient presented to the emergency department at the recommendation of his oncologist for evaluation of his fever, fatigue, weakness, delirium and a left lower extremity lesion. The lesion was the result of a punch biopsy that had been performed three days earlier.
He was initially admitted to the general medical hospital floor for sepsis secondary to purulent cellulitis at the biopsy site. Cultures of the site were obtained and he was started on a combination of piperacillin-tazobactam and vancomycin. During his first hospital night, he experienced an episode of vomiting after which he developed acute respiratory failure, ultimately requiring his intubation and mechanical ventilation, as well as transfer to the critical care unit (CCU). A chest x-ray completed after intubation confirmed a right interstitial infiltrate.

In the CCU, the patient was started on norepinephrine for septic shock. A superficial culture of the lower extremity wound confirmed methicillin sensitive staphylococcus aureus (MSSA). The Infectious Disease service was consulted for assistance in his management. Since this patient appeared to be in septic shock from cellulitis, vancomycin was discontinued in favor of clindamycin for its antitoxin effects. Anidulafungin was also added for broad spectrum coverage for possible fungemia (i.e. presence of fungi or yeast in the blood). His blood cultures and 1,3 β-D glucan level, often elevated in disseminated fungal infections, were negative. However, an endotracheal tube aspiration specimen was remarkable for yeast. Culture sensitivities for MSSA were sensitive to piperacillin-tazobactam, therefore clindamycin and anidulafungin were discontinued.

As the patient became more hemodynamically stable, vasopressors and sedation medication doses were tapered in an attempt to wean him from mechanical ventilation. However, he remained comatose with intermittent fevers. An MRI of the brain revealed possible right thalamic ischemic changes. The Neurology service was consulted due to his persistent neurologic dysfunction. A lumbar puncture was performed demonstrating both an elevated CSF opening pressure and protein level with a predominance of lymphocytes.

On physical exam, a herpetic-appearing lesion on his lower lip was also noted. In the context of his immunosuppression, acyclovir was initiated since there was concern for possible development of Herpes Simplex viral (HSV-1) encephalitis or meningitis. The lip ulceration cultured positive for HSV-1 by PCR (DNA analysis). Initial and 24-hour repeat EEG’s confirmed a diffuse disturbance in cerebral function. Following six days of acyclovir treatment, there was no improvement in the patient’s neurologic
status and his family members elected to withdraw his life-sustaining treatments. Postmortem Lyme IgG was confirmed on ELISA, although neither HSV 1 nor 2 were detected by PCR. After the patient’s death, WNV antibodies were detected in the CSF.

**DISCUSSION**

This patient had multiple risk factors for the neuroinvasive form of WNV infection, most notably his CLL and recent treatment with ibrutinib. Earlier examples have demonstrated that WNV can persist for as long as four months post-mortem in immunocompromised hosts with humoral deficiency from B cell lymphoma. This particular patient’s clinical presentation was unique in that there was no viral symptoms or neurologic changes suggesting acute WNV infection. Initially, he had presented with sepsis due to cellulitis.

As this patient’s hospital course continued, he developed worsening neurologic symptoms that progressed to a comatose state prompting the authors to evaluate him for a possible central nervous system infection. Specific physical exam findings included disorientation, fever, tachycardia, bilateral asymmetric weakness, hypo-reflexia, arrhythmic muscular jerking, tremor, and lack of coordination.

The authors have located other case reports of immunocompromised patients with lymphoma describing similar neurologic findings of lethargy or confusion with weakness and muscular abnormalities. The patients described in these reports were being treated with rituximab. Rituximab is a monoclonal antibody that inhibits the body’s humoral immune response by targeting the CD 20 surface protein on B cells resulting in B cell death. Although this patient did not receive rituximab, he was treated with the chemotherapeutic agent ibrutinib. Ibrutinib operates by binding to Burton’s tyrosine kinase (BTK) receptors, which are important in the signaling pathways B cell proliferation and immune response. By blocking BTK receptors, both healthy B cell and malignant B cell survival and propagation are halted.

It has been suggested in the literature that blunted B cell immunity, whether through a disease process or chemotherapy treatment, predisposes patients to neuroinvasive forms of WNV. Given our patient’s immunocompromised state and
objective findings, we believe that neuroinvasive WNV resulted in this man’s clinical changes. Although neurologic decompensation in an immunocompromised patient should certainly prompt investigation for CNS infection, WNV encephalitis was low on our differential diagnosis because neuroinvasive WNV infections are still quite rare manifestations in Michigan. Additionally, the authors were more suspicious of an alternative infectious etiology due to his cellulitis and HSV-1 positive lip ulceration.

WNV was first detected in Michigan in August 2001. By 2003, 73 of the 83 Upper and Lower Peninsula Michigan counties had been confirmed to have WNV positive birds. The most recent occurrences of WNV treated in the authors’ health system occurred in 2006 when two patients with confirmed WNV were successfully treated and discharged after one week of supportive care.5 Since 1999, Michigan has consistently reported 0.50 to 0.74 per 100,000 residents of neuroinvasive WNV annually.6 Neurologic manifestations of this type of infection are relatively uncommon and therefore not often included in the initial workup of comatose patients.7

Furthermore, while this patient’s MRI was remarkable for a right thalamus abnormality, this finding was nonspecific and did not aid the authors in their diagnosis. The authors have located one documented case of confirmed neuroinvasive WNV infection in a patient with CLL demonstrating bithalamic area of T2 hyperintensity.8 These signal thalamus changes may serve as an additional neuroinvasive WNV diagnostic indicator. However, the gold standard for diagnosis is still WNV PCR analysis of CSF.

CONCLUSIONS

The mainstay of treatment for neuroinvasive WNV infection is supportive care. There is evidence that intravenous immunoglobins given early may offer some benefit.9 However, the case described in which this approach was used did not alter the disease course and ultimately the patient expired. In retrospect, it is not clear whether diagnosing neuroinvasive WNV earlier would have changed this patient’s outcome. His neurologic symptoms were atypical for most presentations of neuroinvasive WNV infection which delayed the authors’ investigation for CNS infections. This patient’s hospital course was managed in the critical care unit. He received aggressive supportive care and appropriate assistance from consulting services including neurology and infectious disease. After 11
hospital days, his neurologic status did not improve and his life-sustaining care was withdrawn.

This case illustrates how climate and geography should be considered, and ultimately influence, the differential diagnosis of patients presenting with neurological symptoms. Furthermore, as the incidence of WNV increases in Michigan, clinicians must maintain a higher index of suspicion for WNV since objective findings including radiographic and laboratory evaluation are non-specific. This is especially imperative in immunocompromised patients since WNV infection may be one piece of a complicated clinical presentation that can be easily overlooked.

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Case Report

Removal of Misplaced Left Ventricular Single Lead Pacemaker in a Patient Presenting with Recurrent Transient Ischemic Attacks

Andrew Hinojos DO,1 Karl Ilg MD 2

1 Genesys Regional Medical Center Internal Medicine Resident, PGY 3, Grand Blanc, MI
2 Genesys Regional Medical Center Cardiology Core Faculty, Grand Blanc, MI

Corresponding Author: Andrew Hinojos DO, andrew.hinojos@ascension.org

ABSTRACT

HINOJOS A, ILG K. Removal of Misplaced Left Ventricular Single Lead Pacemaker in a Patient Presenting with Recurrent Transient Ischemic Attacks. Spartan Med. Res. J. Vol. 2, No. 1, pp. 64-73, 2017. CONTEXT: Over 200,000 cardiac electronic implantable devices are annually placed in individuals living within the United States. Complications from this procedure can range up to 12%. Inadvertent lead placement into the left ventricle is a rare but recognized complication of implantable cardiac electronic devices. METHODS: This is a retrospective case report of a female patient in her late 70’s who underwent atrioventricular node ablation and misplacement of single lead pacemaker, subsequently presenting with recurrent transient ischemic attacks one month later. RESULTS: Initial electrocardiogram and chest X-ray demonstrated misplacement of her pacemaker in the left ventricle. Medical therapy was attempted, however, patient subsequently underwent extraction via aortotomy with implantation of epicardial pacemaker. CONCLUSIONS: Inadvertent placement of implantable electronic cardiac devices is a rare but well recognized complication. A post-procedure electrocardiogram and chest X-ray should be routinely performed to confirm appropriate lead placement. Procedures to manage this complication are evolving with novel device therapies specifically designed for percutaneous lead extraction. Keywords: cardiac pacemaker, transient ischemic attack, atrioventricular node ablation

INTRODUCTION

It is estimated that over 2.4 million people live with cardiac electronic implantable devices (CEID), with complication rates ranging up to 12%.1,2 The most common CEID-related complications include lead dislodgement, pocket hematoma/bleeding, pneumothorax, and infection.1,3 Inadvertent lead placement into the left ventricle (LV) is a rare but recognized complication of CEID use.2,4-16 This paper presents a case report of a patient who underwent atrioventricular node (AVN) ablation with subsequent misplacement of her single lead pacemaker.
Case Report

A female in her late 70’s with a history of mitral valve repair suffered from long-standing symptomatic atrial fibrillation. After four electrophysiology studies with pulmonary vein isolation, repeat left atrium ablation, and flutter line ablation at the authors’ community hospital, the patient ultimately elected to receive an AVN ablation and implantation of a single lead pacemaker. She opted to go to an outside hospital for this procedure and her AVN ablation was complicated due to her difficult anatomy. According to available documentation, her coronary sinus had an early truncation into three possible venous branches, making it difficult to access the LV for pacing. The procedure was aborted and she instead had a single lead pacemaker implanted by the operating physician. The patient did well post-operatively and she was discharged home.

She presented to the authors’ hospital one month later with an episode of left-sided weakness, slurred speech, and the patient was diagnosed with a transient ischemic attack (TIA). Cardiology and neurology consults were obtained. She had been receiving warfarin for her atrial fibrillation and her international normalized ration (INR) on admission was at a therapeutic level. The authors could not exclude transient subtherapeutic INR levels leading to clot formation and thromboembolic phenomenon from her atrial fibrillation. However, her electrocardiogram (ECG) demonstrated an abnormal finding that provided an important clue for the etiology of her presenting symptoms. Her ECG demonstrated a ventricular paced rhythm with a right bundle branch block pattern (Figure 1). A chest x-ray was performed that demonstrated misplacement of the single lead pacemaker with an atypical posterior curvature path. A computerized tomography (CT) scan was performed which further demonstrated her misplaced single-lead pacemaker traversing the aortic valve into the LV (Figure 2).

As she was already on Coumadin for valvular atrial fibrillation, her target INR level was increased to a goal of 3.0-3.5 and she was discharged home. Four months later, she presented to the authors’ hospital with a second TIA.

Due to her recurrent TIAs from the misplaced lead, the authors decided to pursue surgical retrieval. She underwent pre-operative catheterization to assess any burden of coronary artery disease and a peri-operative trans-esophageal echocardiogram. The patient subsequently had an extraction of her LV pacemaker wire via aortotomy and
implantation of an epicardial pacemaker. To date, the patient has been doing well without any further sequelae.

**DISCUSSION**

Misplacement of CEIDs in the LV is a rare but recognized procedural complication. The most common etiologies occur when a catheter traverses through the interatrial septum, patent foramen ovale or atrial septal defect.\(^2\) Less commonly, leads may perforate the interventricular or the atrioventricular septum and deploy in the LV.\(^4,8,9\) Implantation through an intra-arterial approach that crosses the aortic valve is even more rare.\(^3,9-13\) Our case described a misplaced LV pacemaker lead via a subclavian artery insertion traversing the aortic valve and implanting into the LV.

Complications from a misplaced CEID can result in both significant neurologic and vascular sequelae. Previous reports have indicated a thromboembolic complication rate has ranged from 37 to 67\%.\(^2-4,6\) Cerebral thromboembolic complications are the most serious, ranging from mental confusion to cerebrovascular accident with permanent neurologic deficits.\(^4,5\) Vascular complications most often occur on access of the subclavian artery and extraction of the misplaced CEID.\(^5\) Potential complications from the procedure include bleeding, hematoma formation, loss of brachial and/or radial pulse, and arterial thrombus formation.\(^5\) Less commonly, misplaced CEID involving the left side of the heart can result in damage to mitral and aortic valves or trauma to the coronary arteries leading to myocardial ischemia and/or infarction.\(^4,6,10\)

Both ECG and chest x-rays can provide clues for potential misplacement of ventricular pacemakers. Proper placement in the apex of the right ventricle will demonstrate a left bundle branch morphology (LBBB) on ECG. A right bundle branch block (RBBB) pattern should raise suspicion for left ventricular stimulation due to lead malposition. Although uncommon, a RBBB can result if the pacing electrode enters the coronary sinus and into posterior interventricular vein, inserts into the interventricular septum, or with normal pacing in a dilated right ventricle.\(^5-7,10\) Notably, 8 to 13\% of patients will still have a RBBB morphology on ECG with normal right ventricular pacing.\(^9\) While a post procedure ECG should be performed for confirmation of proper lead placement of every CEID, this test cannot entirely confirm lead placement.
Removal of Misplaced Left Ventricular Single Lead Pacemaker in a Patient with Recurrent TIAs

On chest x-ray, both anterior-posterior (AP) and lateral views are preferable for confirmation of proper pacemaker lead placement. A lateral view film is very important to evaluate positioning since leads placed in the right ventricle have a lateral and forward direction on imaging while placement in coronary sinus or LV have a backward direction on lateral chest x-rays. An abnormal posterior position of the catheter tip on a lateral chest x-ray film should raise suspicion of improper lead placement.\(^{3,5,6,9,12}\) On AP films, a misplaced lead in the LV may present as an abnormally high “takeoff” of the ventricular lead.\(^6\)

A chest x-ray alone cannot confirm malposition of a misplaced lead, as a posterior catheter position can be a result of an electrode in the coronary sinus.\(^{12}\) Thus, AP and lateral films can be used as a tool to confirm proper placement of CEIDs post-implantation. However, further imaging should be pursued if there is any suspicion of lead misplacement.

Confirmation of venous access can be difficult, such as in cases of congenital heart disease where arterial blood may appear darker than expected. Thus, there are maneuvers that the operator can perform to help ensure proper placement of the lead in the venous system. During implantation, the guidewire should always be advanced to the inferior vena cava or the pulmonary trunk to ensure venous access. In addition to the standard anterolateral views under fluoroscopy, left anterior oblique or right anterior oblique views should also be performed.\(^2\) After implantation, a post-operative ECG and pair of frontal and lateral x-rays should be routinely performed to confirm proper pacemaker placement.\(^{10}\)

Finally, echocardiography is the test of choice for confirming position of a misplaced CEID. Echocardiograms can directly visualize implantation and enable the provider to follow the course of the misplaced CEID. Echocardiography can also identify a thrombus that may be attached to the misplaced pacemaker, or pericardial effusion, which may indicate myocardial perforation.\(^{2,5,7,8}\)

Lead removal, however, presents a risk of thromboembolic event, and thrombus may not always be identified on echocardiography.\(^2\) Among those individuals suffering thromboembolic complications, 10% to 20% have had a thrombus identified on echocardiogram prior to extraction.\(^{2,4}\) Thus, preoperative echocardiography cannot be
used to reliably identify presence of thrombus but can be used to confirm lead misplacement.

Treatment of a misplaced CEID is comprised of two options: anticoagulant therapy or surgical removal. Decisions concerning which approach is most suitable are based on patient’s symptoms and surgical risks. General recommendations for inadvertent lead placement in an asymptomatic patient with higher surgical risks are to initiate anticoagulation using Coumadin/warfarin with a goal INR of 2.5 to 3.5. Antiplatelet therapy has been shown to pose a high incidence of thromboembolic events and is not recommended as primary therapy.

Surgical removal is often tried in patients that experience thromboembolic complications despite anticoagulation or for patients with prior scheduled cardiac surgery. More recently percutaneous lead extraction has been performed successfully, although there is a higher risk of dislodging thrombi or fibrotic adhesions as time to extraction increases.

Percutaneous extraction can be performed with simple manual traction, traction devices, sheaths that use laser or electrosurgical energy, or sheaths with rotating threaded tips. Traction devices include specialized locking stylets, snares, sutures, or grasping devices used to engage/entrap and remove the lead or lead fragments. Sheaths require manual advancement over the lead and rely on the mechanical properties of the sheath to disrupt fibrotic attachments. Laser sheaths use fiber optics to transmit laser light while electrosurgical sheaths use radiofrequency energy emitted between two electrodes at the sheath tip to disrupt the fibrotic attachments. Major complications from device extraction is approximately 1.4%. Complications rates are higher with longer implant durations and use of laser extraction technique.

In 2011, Rodriguez et al. described favorable outcomes from both open surgical and percutaneous extraction techniques. The case series published by this group suggested that simple manual traction can be attempted in patients with implantation of less than six months. Older pacemaker leads often have additional fibrosis and may require laser energy for removal.

Although case reports of successful percutaneous removal of chronic leads have been reported, this practice is not generally recommended due to the risk of creating
Removal of Misplaced Left Ventricular Single Lead Pacemaker in a Patient with Recurrent TIAs

...emboli or dislodging thrombi into systemic circulation.\textsuperscript{2,7,13} With developing technologies, percutaneous lead extraction may be reserved for special cases where surgical extraction may be complicated due to a candidate with higher surgical risks.

**CONCLUSIONS**

Misplacement of CEIDs is a rare but recognized complication. This case study presented a patient with a misplaced single lead pacemaker via the subclavian artery implanting into the LV. As the patient presented with recurrent TIAs despite medical therapy, the device was removed surgically via aortotomy. Patients with a CEID who present with neurologic symptoms should be screened for proper lead placement with an ECG and/or set of chest x-rays. Although this patient underwent an open surgical removal, novel technologies designed for percutaneous device extraction of misplaced CEID are continuing to improve.

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TABLES AND FIGURES

Figure 1:
12-lead Electrocardiogram Consistent with Right Bundle Branch Block (RBBB)
Figure 2:
CT Chest Demonstrating Misplaced Single Lead Pacemaker
Case Report

Laparoscopic Paraesophageal Hernia Reduction with Two Point Fixation via Ponsky PEG Tube in a Patient in their early 90s

Catherine T. Petzinger DO,¹ John D. Parmely DO, FACOS ²

¹ Beaumont Health General Surgery Resident, PGY 4, Farmington Hills, MI
² Beaumont Health Program Director of General Surgery, Farmington Hills, MI

Corresponding Author: CT Petzinger DO, cpetzinger@beaumont.org

ABSTRACT


CONTEXT: Paraesophageal hernia (PEH) repairs have been historically controversial due to widely variable clinician opinions. However, there is little research regarding the use of PEH reduction and gastropexy via a percutaneous endoscopic gastrostomy (PEG) tube. Guidelines by the Society of American Gastrointestinal and Endoscopic Surgeons do advise that the use of gastropexy alone is a valid option in patients with high risk of morbidity and mortality, but is associated with high hernia recurrence rates.

CASE REPORT: A male in his early 90s presented with a six-week history of dysphagia, regurgitation and a 30-pound weight loss. Imaging revealed a large PEH and the entire stomach within the thoracic cavity. Despite the patient’s age and significant risk factors, it was determined that he required surgical intervention due to the severity of his symptoms. The safest course of action was reduction of PEH with two-point gastric fixation, rather than a prolonged repair of the hiatus or mesh implant.

RESULTS: Due to the patient’s significant surgical risks, it was determined that the safest surgical approach would be laparoscopic reduction with dual gastropexy via PEG tube gastropexy. This approach was quick, without encroachment into the mediastinum and avoided any complications that mesh implantation could have posed.

CONCLUSIONS: Gastropexy is a relatively simple technique with minimal tissue dissection that is tolerated well in elderly patients or those with decreased cardiac and pulmonary status. Regardless of the surgical PEH approach, there are inherent hernia recurrence rates. Keywords: paraesophageal hernia reduction, gastropexy, percutaneous endoscopic gastrostomy (PEG) tube

INTRODUCTION

Hiatal hernias are defects in the diaphragm that can allow for aberrant organs to migrate into the chest, and generally categorized into four types. The first type, a Type I hernia, is a sliding hernia in which the gastroesophageal (GE junction) migrates above the diaphragm, accounts for 90% of all hiatal hernias.¹ Type II-through-IV hernias are categorized as paraesophageal hernias (PEH). Type II hernias have a fixed GE junction below the diaphragm and the superior portion of the stomach (the fundus) is found above the diaphragm. Type III hernias are the most common defects, with
both the GE junction and a portion of the stomach displaced above the diaphragm. Type IV hernias entail all the components of Type III defects with another organ (small bowel, colon, etc.) herniated above the diaphragm.\textsuperscript{1}

A recent study examining outcomes in “giant” PEH demonstrated that presenting symptoms can be extremely variable.\textsuperscript{2} In this prior study with over 500 patients, the most common presenting symptoms included heartburn (59\%), postprandial chest pain (40\%), cough (16\%), shortness of breath (53\%), early satiety (54\%), dysphasia (47\%), and anemia (37\%).\textsuperscript{2} PEH are also more frequently seen in women and the elderly population who may have tolerated their symptoms for years.\textsuperscript{3}

PEH defects are usually asymptomatic, especially Type I. However, a study by Shihvo et al. examined the possible fatal complications associated with PEH.\textsuperscript{4} Major complications included: intrathoracic incarceration of the stomach, gastric volvulus, bleeding, perforation, or decreased pulmonary function.\textsuperscript{4} Based on these risks, this group of earlier authors advocated for repair of PEH in symptomatic patients unless estimated mortality risks of greater than 10\%.\textsuperscript{4} Generally, PEHs tend to increase in size over time, and the annual incidence of acute symptoms requiring emergency surgery is estimated to be between 0.7 and 7.0\%.\textsuperscript{5} Since a larger-sized hernia can make surgery more technically difficult, patients requiring emergent surgery for complications of PEH have a much higher morbidity and mortality rate than those receiving elective procedures.\textsuperscript{5}

Historically, debates concerning different preferred techniques for PEH repairs have endured.\textsuperscript{6} Techniques ranging from open versus laparoscopic to with or without mesh implantation, as well as interventions for symptomatic PEH have evolved greatly over the years.\textsuperscript{6} However, the morbidity and mortality associated with surgical PEH repair has also been decreasing throughout the years.\textsuperscript{7} The latest 2013 Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) guidelines suggest laparoscopic hiatal hernia repair is now as effective as open trans-abdominal repair.\textsuperscript{7} The principles of repair consists of the reduction of the hernia into the abdominal cavity and fixation so that contents cannot rotate within the peritoneal cavity or herniate back into the thorax.
This is usually accomplished with a fundoplication, a fixation of the anterior gastric wall to the abdominal wall, and the repair of the diaphragmatic crura, the tendons of the diaphragm that surround the opening for the esophagus. This crura defect has historically been closed with mesh. Plication of the stomach to the anterior abdominal wall by temporary gastrostomy tube could also protect against subsequent gastric volvulus. However, there is little research or evidence to support the use of gastropexy alone to manage PEH. The most recent SAGES guidelines advise that gastropexy alone is a valid option in patients with high risk of morbidity and mortality.6

At time of operation, an older age, lower body mass index, and a larger preoperative hernia are significantly associated with an increased rate of postoperative morbidity.7 Fundoplication and crural repair can be lengthy and difficult especially in patients who have very large PEH defects. Although some surgeons use mesh to close such defects, there are intrinsic complications with mesh implantation. Complications include mesh migration, infection, dysphagia and erosion of mesh into surrounding structures. Even though gastropexy alone comes with an increased risk of recurrent herniation, it remains a viable surgical option for medically high-risk patients.

Case Report

This case report concerns a male in his early 90s with a pertinent past medical history of smoking and chronic obstructive pulmonary disease (COPD), right bundle branch block arrhythmia, hypertension and hypothyroidism. He presented to his primary care provider’s office with a six-week history of complaints of dysphagia (difficulty swallowing) with regurgitation of food as well as reported 30-pound weight loss. He denied any previous gastroesophageal reflux symptoms. An outpatient CT scan of his abdomen revealed a large PEH with the entire stomach within an intra-thoracic PEH defect. The patient presented to the authors’ surgical office to discuss options.

Despite the patient’s age and significant risk factors (i.e., smoking, hypertension, large hernia, poor nutritional status and low body mass index), the authors determined that the patient needed surgical intervention due to the severity of his acute obstructive symptoms. They concluded that the safest course of action was reduction of PEH with two-point gastric fixation with percutaneous endoscopic
gastrostomy (PEG) tubes, rather than subject the patient to a longer PEH repair with reinforcement mesh or fundoplication. The authors also had concerns about the patients’ nutritional status due to his significant weight-loss and its effects on his postoperative healing, making this shorter less invasive alternative ideal for the patient.

**Surgical Intervention and Hospital Course**

Intraoperatively, the patient was found to have a large hiatal defect with the majority of the stomach within the paraesophageal defect and a gastric volvulus. The stomach was easily reduced into the abdominal cavity without any dissection into the mediastinum. The gastric volvulus was also reduced. Subsequently, the gastric outlet was noted to be patent on evaluation with a gastroscope. There was also no evidence of gastritis or esophagitis on EGD. Two Ponsky PEG tubes were then placed using endoscopic/percutaneous technique with laparoscopic visualization for positioning of the PEG tubes. The PEG tubes were placed at the proximal and distal stomach, performing a pexy (fixation) of the anterior wall of the stomach to the abdominal wall.

Postoperatively, the patient was admitted to the hospital for monitoring and postoperative care. Although he was at first hesitant to resume eating, he resumed a regular diet after some encouragement without signs of dysphagia. An Upper GI Study was performed on postoperative day #1 showing the cardia of the stomach in the left hemithorax. However, the remainder of the stomach was within the abdomen and there was no gastric outlet obstruction or volvulus. The patient was discharged home on postoperative day #2 without any signs of dysphagia. The patient was followed closely on an outpatient basis for one postoperative month and continued to tolerate a regular diet, gaining weight without enteral supplementation. After the post-op month, both Ponsky PEG tubes were removed without any recurrence of symptoms.

**DISCUSSION**

Paraesophageal hernias, Types II-IV should be repaired in a timely manner due to the significant comorbidities associated with these defects. These hernias will continue to increase in size over time, making the non-emergent repair of these hernias necessary in younger patients. Earlier repairs result in fewer intra-thoracic adhesions, making the dissection of the hernia from the thoracic cavity less complicated. Dilation
of the hiatus and stretching of the cura also increases with time, which can also make surgical repair more difficult. The approach and type of surgery performed should be chosen based on the patient factors and fit the patients’ surgical profile. Elective repairs avoid future complications and improve patients’ function.3

Traditional management of PEH calls for a lengthy and risky surgical approach that is not always appropriate for patients with advanced age and multiple co-morbidities. In a 2010 article by Luketich et al., 662 patients who underwent laparoscopic giant PEH repairs were followed for 10 years.9 These patients underwent screening esophagrams which showed hiatal hernia recurrence of up to 15.7% although only 3.2% had return of their symptoms. In this 2010 study, those patients, who underwent complete dissection of the intra-thoracic hernia sac, crural repair and mesh application still had a 15.7% recurrence rate.9 In a similar study from Antonoff and colleagues, their group of patients underwent similar steps for their PEH repairs with morbidity rates of 8.2% and recurrence rates of 5.5%.10 These authors attributed their success rates to observing a minimally invasive approach while still using the fundamentals of open repair.10

Some surgeons are proponents of adding a wrap of the fundus of the stomach after the hernia is reduced and mesh is fixed to prevent the occurrence of GERD. One German randomized controlled pilot study with 40 patients compared Laparoscopic mesh-augmented hiatoplasty with simple cardiophrenicopexy (LMAH-C) versus Laparoscopic mesh-augmented hiatoplasty with fundoplication.11 Their data showed that recurrence rates were similar between the two (33% and 21%, respectively). However they proposed that fundoplication be added to all repairs due to the risk of new onset GERD that occurred in a significant amount of patients who underwent LMAH-C (53%) in comparison to those who underwent LMAH-F (17%). Moreover, adding a fundoplication also added half an hour to surgery (Mean 153 minutes; range 90-250 minutes) in comparison to LMAH–C (Mean 124 minutes: range 85-210 minutes).11

Different surgical approaches, techniques and modalities for PEH repair add an increased amount of time under anesthesia for patients who are elderly and frail, increasing their morbidity and possible mortality risks. Mortality rates after emergent
PEH repair are estimated at 5.4-8% and 0.8-1.4% after elective PEH, and frail patients have higher mortality risks.5

Our approach in this case was not only unique in the use of dual PEG tube insertion to prevent gastric volvulus, but also allowed a chronically ill patient to undergo surgical intervention for which he otherwise would not have been a candidate. Due to the significant risks attributed with this patient in their early 90s, the authors determined that the safest approach to his large PEH would be laparoscopic reduction of the PEH with gastropexy. This approach was relatively quick (76 minutes), without encroachment into the mediastinum and avoided any complications mesh implantation could pose. SAGES guidelines do report that morbidity and mortality of gastropexy is significantly lower than other more invasive PEH repairs.7 However, gastropexy alone has not demonstrated the same efficacy as formal repair of a PEH and should be reserved for patients with significant comorbidities.7

Gastropexy is a relatively simple technique with minimal tissue dissection that is generally well tolerated in the elderly population and those with decreased cardiac and pulmonary status.13 Regardless of the approach to PEH repair, there are inherent chances of recurrence. In a study from Daigle and associates, laparoscopic PEH repairs using a modified Boerema anterior gastropexy (i.e., fixation to the abdominal wall with nonabsorbable sutures putting the esophagus under some tension to form an “angle of His”) was completed without fundoplication at multiple centers.14 Out of 101 patients, 70% had no postoperative reflux with recurrence rates of 16.8% when followed on endoscopy or barium swallow evaluation.14 Surgical intervention and approach should therefore be tailored to the patient, with risks and benefits carefully weighed. In this case, the patient tolerated dual gastropexy alone with complete resolution of symptoms without the increased accompanying risks of crural repair and mesh implantation.

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**TABLES AND FIGURES**

**Figure 1:**
Anatomy of the Esophagus, Gastroesophageal (GE) Junction, and Stomach
Displaying Normal Anatomy and the Four Types of Hiatal Hernias

A. Normal.
B. Sliding or type I hiatal hernia.
C. Paraesophageal or type II hiatal hernia.
D. Type III hiatal hernia
E. Type IV hiatal hernia (note colon to the left of the herniated gastric fundus).

(Illustrations by Lindsay Agema and Christian B. Rodriguez.)
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Figure 2:
CT Scan of Abdomen Showing the Stomach Completely Above the Diaphragm.
Figure 3:
Laparoscopic View of Paraesophageal Hernia and Crural Defect
Figure 4:
Laparoscopic View After Reduction and Two-Point Ponsky Fixation to the Anterior Abdominal Wall.
Carbon Monoxide Poisoning: The Great Imitator

Christopher Velasquez MS4,1,3 Tye Patchana MS4,2,3 Brian McParland MS4,1,3 Jonathan Lovy DO,3,4 Ahmad Maarouf MD,3,5 Christopher Whitty PhD, MD 3,6

1 Michigan State University College of Osteopathic Medicine, East Lansing, MI.
2 Lake Erie College of Osteopathic Medicine, Erie, PA.
3 Beaumont Hospital Southshore Campus, Trenton, MI.
4 Beaumont Hospital Internal Medicine Residency Program Director Southshore Campus, Trenton, MI.
5 Beaumont Hospital Department of Critical Care Medicine Southshore Campus, Trenton, MI.
6 Michigan State University Department of Neurology & Ophthalmology, East Lansing MI.

Corresponding Author: Christopher Velasquez, velasq37@msu.edu

ABSTRACT
VELASQUEZ C, PATCHANA T, MCPARLAND B, LOVY J, MAAROUF A, WHITTY C. Carbon Monoxide Poisoning: The Great Imitator. Spartan Med. Res. J. Vol. 2 No.1, pp. 86-97, 2017. CONTEXT: Carbon Monoxide (CO) is one of the leading causes of poison deaths in the United States. Signs and symptoms are clinically variable secondary to inconsistent targeting of highly metabolic tissues by the gas. METHODS: We report a case of a man in his early to mid-30’s presenting to the emergency department with mental status changes, fatigue, headache, and flu-like symptoms for three days. The patient had been working on his motor vehicles in the garage during this time, using a portable diesel-powered space heater to keep warm. RESULTS: Subsequent neurology and cardiology workup demonstrated bilateral globus pallidus (GP) lesions on brain imaging, increased non-myocardial infarction troponin levels, carboxyhemoglobin (COHb) level of 3.8%, elevated liver enzymes, and acute kidney failure. In this setting of his delayed presentation as a smoker with carbon monoxide poisoning, carboxyhemoglobin levels alone become less reliable. This report investigates the use of bilateral GP lesions, the most frequently affected structure, as well as damage preference to highly metabolic tissues to assist in diagnosis and prognosis for CO poisoning. CONCLUSIONS: Our observations can be used for further study of the relationship between bilateral GP necrosis and initial presentation and outcome of patients experiencing CO poisoning leading to earlier recognition, treatment, and decreased morbidity/mortality. Keywords: carbon monoxide, globus pallidus, basal ganglia, carboxyhemoglobin

INTRODUCTION
Carbon monoxide (CO) is the most common cause of death from accidental poisoning in the world.1 Although the United States Center for Disease Control and Prevention (CDC) states that there are approximately 500 accidental non-fire related CO poisoning deaths every year, other estimates put this number as high as 1,000-2,000
annual cases.\textsuperscript{2} In addition, CO poisoning is responsible for approximately 50,000 annual emergency room visits.\textsuperscript{3}

However, the estimated reporting of CO-related morbidity and deaths is likely underreported since the United States does not have a comprehensive national system of CO surveillance.\textsuperscript{4} In addition, misdiagnosis can occur due to variable clinical presentations and nonspecific signs and symptoms.\textsuperscript{4} The variability and nonspecific symptomatology is largely due to the colorless, odorless features of CO gas combined with the nature, severity, and duration of exposure.\textsuperscript{5}

Exposures most frequently occur in winter months due to smoke inhalation from fires, motor vehicle exhaust, or the burning of fuel (e.g., oil, wood, coal, gasoline, natural gas) in poorly functioning or improperly ventilated devices (e.g., heating systems, stoves, charcoal grills, portable generators, electrical heaters, etc.). In this report, we present a severe case of CO poisoning that demonstrates how brain imaging may provide an essential clue during provider diagnosis and prognosis of exposures.

**Case Description**

A Caucasian male in their early to mid 30's presented to an emergency department (ED) by ambulance with mental status changes. The individual was a smoker without history of medical problems. However, providers suspected drug overdose due to his history of suboxone and hydrocodone use in the past and he received 8 mg. of Narcan prior to arrival without improvement. Initial pulse oximetry was especially low in the 50% range and he had been treated by paramedics with high-flow oxygen via nonrebreather mask.

His wife reported that the patient had experienced increased drowsiness and fatigue during the past three days, spending most of his time lying on the couch with associated flu-like symptoms and headache. The patient's wife was unable to wake the patient from sleep on the day of his presentation, even after splashing a bucket of cold water onto his face, prompting her to call 911. He had also had one episode of vomiting enroute to the ED.

Upon his arrival, the patient had a low level of consciousness (Glasgow Coma Scale of 3) and his initial vital signs included a temperature of 97.4\textdegree{} F, blood pressure of 96/49, heart rate of 110, respiratory rate of 25 breaths/min and an improved pulse
oximetry reading of 96%. He was immediately intubated to maintain his airway. Physical examination was otherwise unremarkable. Hypoglycemia was absent, and his ECG was normal. An initial CT scan of the head was read as negative for acute intracranial pathology. Urine toxicology was also negative.

Due to the patient’s obesity, lumbar puncture was particularly difficult and multiple attempts in the ED were unsuccessful. Interventional radiology was consulted to perform lumbar puncture with cerebral spinal fluid (CSF) results pending. He was admitted to the Intensive Care Unit with respiratory isolation and his working differential diagnosis included meningitis, for which he was started on empiric antibiotics. Upon neurological consult and evaluation, additional history revealed that the patient had been working on several motor vehicles in the garage during the past week and using a portable diesel space heater. Upon reviewing laboratory studies, the patient’s combined acute liver failure (i.e., AST of 1144, ALT of 1692) and kidney failure (Creatinine of 2.05) indicated global hypoxia.

Further reevaluation of the patient’s initial head CT noted bilateral hypodensities in the globi pallidi (Figure 1). An MRI was ordered, revealing restricted diffusion on diffusion weighted imaging with symmetric bilateral involvement of the globi pallidi (GP). Hypointensity to surrounding brain parenchyma was noted on T1 Axial MRI, with corresponding hyperintensity on T2 Axial MRI. MRI films are included in this report (Figures 2 and 3). An arterial blood sample revealed a carboxyhemoglobin (COHb) level of 3.8% (above the absolute upper normal limit of 3% for smokers). Per his wife, the patient had smoked one to two packs of cigarettes daily for the past 18 years.

The lumbar puncture performed by interventional radiology revealed no active evidence of meningitis. Blood, sputum, CSF, and urine cultures remained negative throughout hospitalization. On hospital Day 4, the patient was extubated but remained obtunded.

On Day 5 of his hospital stay, the patient became alert and oriented and a more complete review of systems was able to be obtained. The patient complained of fevers, chills, cough, and global myalgia. He was restless and could not find a comfortable position at night. His respiratory rate had continued to be increased (29/min). He remained on Zosyn for aspiration pneumonia coverage and his liver enzymes began to
normalize (i.e., AST 65, ALT 749). An electroencephalogram (EEG) that had been ordered by the Neurology service showed slowed waveforms with no seizure activity.

Cardiology consult following a non-MI troponin increase (0.19) agreed with the assessment of CO poisoning and advocated for continued supportive care. The patient was moved on Day 5 from the intensive care unit to the general medical floor. He was discharged home two days later.

**DISCUSSION**

CO is an odorless, tasteless, and invisible gas produced by incomplete combustion of carbon containing compounds. Exposures are most frequently seen during the winter months in cold climates due to accidental smoke inhalation from fires or use of gasoline powered portable generators, space heaters, or camp stoves in poorly ventilated areas. Providers should also consider the possibility of an intentional CO exposure during a suicide attempt. Exposure in the summer months most commonly occurs from boats (i.e., primarily from engine or generator exhaust). Exposures are also more common after natural disasters such as hurricanes or floods due to the use of portable fuel and electricity for heating, cooking, and cleanup. For example, there were 51 cases of CO poisoning reported after Hurricane Katrina in 2005 by hyperbaric oxygen facilities in Alabama, Louisiana, and Mississippi.

Since CO is inhaled, it diffuses across the alveolar membrane and into the pulmonary capillaries to form carboxyhemoglobin (COHb) inside red blood cells. Since the most common cellular target of CO is heme, it tends to bind to heme-containing proteins including hemoglobin, cytochrome C, cytochrome P450s, and myoglobin. Oxygen delivery to tissues is reduced and the tissues at greatest risk are those with high metabolic demands which may result in global hypoxia as exemplified in our patient.

This gas also disrupts ATP production by binding Cytochrome C Oxidase in cardiac myocyte mitochondria as reflected in this man’s non-MI related troponin increase. Interestingly, several studies report that CO-poisoned patients presenting with acute cardiac injury have significantly higher long-term mortality and neurologic sequelae. For this reason, it is important for providers to obtain an ECG and cardiac biomarkers to identify myocardial injury in the workup of severe CO poisoning.
It is also significant to note that there is no clear relationship between CO-oximetry measured COHb levels with symptoms. The first and overall most common symptom is headache, as the brain is most sensitive to CO poisoning. Beyond classically known signs and symptoms (i.e., headache, fatigue, flu-like/viral illness, nausea, vomiting, dizziness, shortness of breath, chest pain, and pink or cherry-red skin), CO poisoning has been associated with increased long term morbidity & mortality. Specifically, patients with CO poisoning have been shown to have three-fold increases in mortality compared with matched, unexposed individuals at a median post-exposure follow-up period of 7.6 years.

In the appropriate clinical context, a serum COHb level over 3% for nonsmokers and over 15% in smokers per arterial or venous blood confirms the diagnosis of CO poisoning. However, levels may be low if the patient has already received supplemental oxygen or if delay occurs between exposure and testing. Pulse oximetry is also inaccurate because of the similar absorption characteristics of oxyhemoglobin and carboxyhemoglobin. Combined with nonspecific sign and symptom presentation, it can be very difficult to make a firm diagnosis of CO poisoning, resulting in increased morbidity and mortality and underreporting of the deadly disease.

When attempting an earlier recognition of CO poisoning, one option may be to explore the subtle and often overlooked neuroimaging findings that continue to be helpful in narrowing down this difficult diagnoses, particularly in cases of encephalopathy where patient history is not attainable. Providers need to conside that other specific toxins (e.g., methanol, lead, etc.) can selectively affect distinct areas of the brain.

The GP, a deep subcortical structure at the inferior base of the brain, is the most frequently affected structure in CO poisoning and usually damaged immediately, symmetrically, and bilaterally. The leading theory for why CO specifically targets the GP is that it contains the highest iron content in the brain. The ischemic CO induced lesions in the bilateral GP of the basal ganglia can be seen as symmetric hypodensity on CT, hyperintensity on T2, hypointensity on T1, and restricted diffusion on diffusion weighted imaging MRI. The patient described in this case report demonstrated these classic findings on imaging that ultimately confirmed the diagnosis (Figures 1, 2, and 3).
The cornerstone treatment of CO poisoning is administration of high flow oxygen via non rebreather mask regardless of the pulse oximetry readings. Hyperbaric oxygen therapy has continued to be a controversial intervention and only one high quality randomized trial has indicated its use resulting in improved neurological outcomes at 12 months. Additionally, authors of a recent retrospective review from Taiwan evaluating 25,757 patients with CO poisoning demonstrated a survival advantage in patients treated with hyperbaric oxygen. However, there is currently no absolute indication and standardization for hyperbaric oxygen therapy and further randomized controlled trials are needed. As of January 2017, the American College of Emergency Physicians has only assigned a level B recommendation for the use of hyperbaric oxygen therapy.

CO exposure may be prevented by advocating CDC recommendations to install a battery-operated or battery back-up CO detector in patients’ homes, basements and garages, checking/replacing the battery when changing clock settings each spring and fall. Since CO is slightly lighter than air, carbon monoxide detectors have historically been placed on the ceilings or high up on a wall. However, CO can mix and diffuse in its environment and detectors that are placed lower on the wall are generally adequate.

CONCLUSIONS

Carbon monoxide poisoning is a complex clinical condition due to its variable clinical presentation and nonspecific symptoms. It is therefore crucial to obtain a detailed history and keep this diagnosis high on the differential in any patient with headache and/or mental status changes. Although always difficult in an unstable patient presenting to the ED, a detailed focused history will remain the foundation in practicing medicine.

Especially during the winter months, primary care providers should ask specific questions to obtain historical information concerning space heater or generator use, work in enclosed spaces such as a garage, prior suicide attempts, or multiple family members presenting at once with similar complaints. As one of the leading causes of poison deaths in the United States, CO poisoning requires that providers in all healthcare settings recognize its prevalence, presentation, and treatment. Unfortunately, carbon monoxide poisoning classically presents with nonspecific symptoms and current diagnostic modalities including carboxyhemoglobin levels are often unreliable as indicated in this case report.
Perhaps this diagnosis may be more consistently revealed when a suspicious history is combined with findings of symmetric bilateral lesions of the GP on brain imaging. Future research is required to focus on the diagnostic and prognostic usefulness of neuroimaging which may ultimately identify novel interventions for CO poisoning victims.

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FIGURE 1:
CT Head Without Contrast Demonstrating Symmetric Hypodensity of Bilateral Globus Pallidus (GP)
Figure 2:
T1 FLAIR MRI Brain Showing Hypointense GP Relative to Surrounding Brain Parenchyma
Figure 3:
AXIAL T2 FLAIR MRI Brain Showing Hyperintense GP Relative to Surrounding Brain Parenchyma
Brief Report

Thermal Energy Produced by Medium Velocity Pistol Projectiles and the Effects on Peripheral Nerve Tissue

Alexander J. Colen DO,1 Logan F. Hanson DO,2 Germaine R. Frits DO,3
Cameron G. Hanson BS

1 Beaumont Health Orthopedic Resident, PGY 4, Farmington Hills, MI
2 Beaumont Health Orthopedic Resident, PGY 5, Farmington Hills, MI
3 Beaumont Health Attending Orthopedic Surgeon, Farmington Hills, MI

Corresponding Author: Alexander J. Colen DO, Alexander.Colen@gmail.com

ABSTRACT

COLEN AJ, HANSON LF, FRITZ GR, HANSON CG. Thermal Energy Produced by Medium Velocity Pistol Projectiles and the Effects on Peripheral Nerve Tissue. Spartan Med. Res. J. Vol. 2, No. 1, pp 98-110, 2017. CONTEXT: Sidearm pistols are more frequently involved in violent crimes due to their relatively small size and ability to be concealed. The extent to which the thermal energy released from such medium velocity pistol projectiles contributes to peripheral nerve injury requires further testing. The purpose of this paper is to describe a method to quantify how much thermal energy is released during impact of medium velocity pistol projectiles and report how thermal energy contributes to peripheral nerve injury. METHODS: Eleven seven-centimeter segments of radial, median, and ulnar nerves were dissected from a thawed fresh frozen cadaver. The nerve segments were placed in a 10% ballistics gel block, one centimeter from the end of the block nearest the shooter. A series of 115-grain 9 mm. NATO-classified ammunitions were fired through the nerve and ballistics gel construct with a pistol. The impacts were recorded with a high-speed infrared camera and nerve samples were sent for histologic analysis by two board-certified pathologists. RESULTS: The average velocity of the projectiles were 391 m/s, 95% CI [387-395 m/s], with an average kinetic energy of 572.0 J, 95% CI [560.0-583.0 J]. The average observable temperature of the ballistics gel/nerve prior to impact was 28.8°C±0.6°C, 95% CI [26.4-30.3°C]. Average observable temperature of the surrounding ballistics gel/nerve during projectile impact was 55.1°C±2.4°C, 95% CI [51.3- 62.1°C], yielding an average observable increase of 26.4°C±3.2°C, 95% CI [20.2- 35.4°C]. An adjusted temperature increase was also surprisingly high 63.4°C ± 3.2, 95% CI [57.2 – 72.4°C]. Histology reports of the impacted nerve tissue failed to show any sign of thermal or even crush injury. CONCLUSIONS: Medium velocity handgun projectiles release a significant amount of heat energy when impacting a substance similar to human tissue. The authors’ temperature data points were greater than those previously reported to cause thermal injury to peripheral nerves. The authors’ findings suggest that nerve injury after collision with pistol projectiles may be secondary to thermal injury in addition to the classic model of concussion and penetration given our documented levels of heat generated during impact. Keywords: gunshot wounds, thermal necrosis of nerve tissue, peripheral nerve injury
INTRODUCTION

In 2011, there were a total of over 478,400 fatal and nonfatal violent crimes committed with a firearm in the United States, leading to a total of 11,101 deaths.\textsuperscript{1} Between 1999 and 2008, Bartkiw et al. at the Detroit Receiving Hospital, described 2,808 reported wounds inflicted by firearm projectiles.\textsuperscript{2} According to US Department of Justice estimates, nine of ten violent firearm related non-fatal crimes are committed with a sidearm pistol as opposed to a rifle or shotgun.\textsuperscript{1} In 1994, 84\% of firearm-related homicides were committed with a handgun.\textsuperscript{1} In 2001, 15\% of state and 13\% of federal penitentiary inmates carried a handgun at the time of the offense compared to 1.3\% of state and 1.3\% of federal inmates with rifles. Shotguns were involved in 2.4\% of state and 2.0\% of federal inmate crimes.\textsuperscript{1}

It has been speculated that pistols tend to have such a higher likelihood of being involved in violent crimes due to their relatively small size and ability to be concealed.\textsuperscript{3} “Saturday night specials” are easily obtained illegal firearms that can be purchased for as little as $50 and found on the black-market without background checks or federal regulation.\textsuperscript{3} These types of pistols have often had their serial numbers removed, and may be linked to previous crimes.\textsuperscript{3}

Several federal law enforcement branches have adopted use of 9-millimeter (mm.) NATO-classified rounds for reasons including high round capacity and relatively low user recoil. Modern day hollow point ammunition (i.e., projectiles which have a concave distal tip) expand once contacting an intended target, resulting in increased soft tissue damage and an increased level of energy transmission from the projectile to the target.

Differences in projectile velocities between categories of firearms are a major factor in tissue damage. Projectiles are categorized as “low velocity” (less than 360 meters per second m/s), “medium velocity” (370–760 m/s), and “high velocity” (greater than 760 m/s).\textsuperscript{4} Pistols rounds are typically in the medium to low velocity range. Two mechanisms of tissue damage from bullet impacts are shock wave cavitations causing indirect trauma via transmission of energy through the surrounding tissues (i.e., temporary cavity), and damage by direct impact and penetration (i.e., permanent cavity).\textsuperscript{4,7} Although larger, slower projectiles tend to damage the tissue via a direct impact crush mechanism, smaller high velocity projectiles disrupt soft tissues via shock wave stretch cavitations.\textsuperscript{7}
Xu et al.\(^8\) described the manner in which low-grade thermal injury to myelinated nerves results in a delayed, selective loss of myelinated fibers. Secondary heat induced angiopathy in which direct axonal damage was also seen in unmyelinated C-fibers with temperatures between 47°C and 58°C.\(^8\) The mechanism and severity of hyperthermic insults affecting nerve tissue has been reported in several articles.\(^5,8,9\) However, none of these previous studies had examined the degree to which tissues are heated during impact with medium velocity pistol projectiles.

For this project, the authors hypothesized that there would be significant release of thermal energy into the surrounding tissue near the impact site of medium-velocity 115-grain 9 mm. NATO-classified hollow point projectiles. They also hypothesized that the immediate histologic findings would fail to demonstrate gross thermal injury to study nerve segments.

**METHODS**

Eleven 7-centimeter (cm.) segments of median, ulnar, or radial nerves were first dissected from a fresh frozen cadaver upper extremity immediately after being thawed. Nerve segments were placed at room temperature in a 15.2 cm. x 15.2 cm. x 40.6 cm. 10% gelatin ballistics block, one cm. from its edge closest to the shooter. The 10% ballistics gel block with embedded nerve tissues was placed three meters from the firearm.

An electronic digital chronograph (Competition Electronics® Rockford, IL) was placed directly in front of the ballistics gel block to measure the velocities of the projectiles before impact (Figure 1). An infrared camera (IR) was also placed directly lateral to the pistol, separated by a ballistic wall for protection of the sensitive electronics and to record thermodynamics profile of the projectile prior, during, and immediately after impact. The IR camera was specifically calibrated to read temperature changes in the ballistics gel.

Standard pressure 115-grain jacketed hollow point 9 mm. NATO-classified (Underwood® Sparta, IL) ammunition with an average velocity of 391.5 m/s was used for the trial. A 9 mm. 1911 pistol with an 11.2 cm. (4.4-inch) barrel was used. The pistol was fired directly at the nerve embedded in the ballistics gel, penetrating the nerve, from a distance of 3.0 meters. This distance of three meters had been chosen given that 79% of law enforcement officers who were killed with a pistol between 2006 and 2015 were at
distances of 0-to-10 meters. This distance was also selected to provide an adequate distance for muzzle blast to not be a factor with our temperature readings. Five minutes were allowed between trials to allow for the ballistics gel temperature to stabilize back to room temperature as confirmed by the IR camera.

The impacted nerve tissue segments were then removed, wrapped in normal saline soaked gauze, placed in individual storage containers, and placed on ice. The nerve tissue was then sent to the Beaumont Health Farmington Hills campus histological laboratory. The samples were fixed in 10% zinc formalin for approximately 72 hours, sectioned at 5 mm. intervals and embedded in paraffin. Four-micrometer (μm) thick sections were mounted on charge slides, deparaffinized in xylene, hydrated in a graded series of alcohol and stained with hematoxylin and eosin (H&E) for histologic evaluation.

A high-speed IR camera (FLIR Systems X6901sc® Wilsonville, OR) was used for the experiment. The FLIR X6901sc utilizes an Indium Antimonide (InSb) infrared detector with a broadband (3–5 μm) spectral sensitivity and F/3 aperture. The temperature range selected was from 0ºC to 208ºC ± 2ºC with a sensitivity of <20mK. The frame rate was between 1004.6 frames per second to 2000 frames per second with a resolution of 640x512. Data was recorded to the camera’s internal solid-state drive then transferred to a computer for analysis. Each recording was labeled with the active nerve trial (N1-N11) data collected during a three-second period (3004-6000 frames).

The IR data regarding post-impact temperatures was derived from the transverse shockwave of the impact in the gel which exposed the internal environment of the gel as well as the impacted nerve. Temperature readings were only obtained at the entry point of the gel where the nerve was located (Figure 2). After analyzing each frame of each trial, the authors had identified the maximum observable temperatures within the projectiles path along with that of the projectile itself.

The area of the maximum temperature of approximately 2-4 mm ± 1 mm was determined by using the ballistic gel dimensions as a scale reference, correcting for potential lens distortion. Each temperature reading of the impacted nerve segment and surrounding ballistics gel was sustained for approximately 2 to 3 frames, at 2000 frames per second, or 1 to 1.5 msec. The temperature of the projectile was kept consistent until impact with the ballistics gel.
Once data from the X6901sc solid-state drive was transferred to the computer, FLIR Research® IR Software was used for analysis. This software allowed temperature identification for each pixel selected, in addition to temporal plots, histograms, digital counts, and radiance.

The authors generated histogram plots concerning the areas of interest, and spatial temperature point data were used to localize the maximum temperatures of projectile and ballistics gel, and nerve prior, during, and following the impact. Each frame was individually analyzed to identify the maximum temperature throughout the projectiles path (Figure 3).

RESULTS

Eleven nerve samples were used for this study with a length of 7 cm each. Average velocity of the 115-grain, 9 mm. NATO ammunition immediately before impact with the ballistics gel was 391.5 m/s, 95% CI [387.0-395.0 m/s] with an average kinetic energy of 572.0J, 95% CI [560.0-583.0J]. The average observable temperature of the ballistics gel immediately before impact was 28.8°C ± 0.6°C, 95% CI [26.4-30.3°C]. The average observable temperature of the bullets before impacting the gel was 33.3°C ±1.6°C, 95% CI [32.0-35.5°C] which was less than we originally expected. The average observable maximum temperature of the gel during impact was 55.1°C ± 2.4°C, 95% CI [51.3-62.1°C]. However, the average observable increase in temperature of the ballistics gel during impact was a surprisingly high 26.4°C ± 3.2°C, 95% CI [20.2- 35.4°C] (Table 1). Our adjusted average maximum temperature was calculated to be 63.4°C ± 3.2, 95% CI [57.2 – 72.4°C].

Histological evaluation of the nerve portions which had been penetrated by the projectiles were determined by gross examination prior to sectioning and could be readily identified by deformation of the normal tubular structures. On H&E evaluation, both the nerve segments that had been penetrated by the bullet and nerve tissues distal to the area of bullet impact appeared identical. In particular, there was no evidence of thermal alterations or even crush injury of the sample near or distal to the bullet impact site.
DISCUSSION

From this project, the authors were able to observe and record how much thermal energy was released into nerve tissue embedded 1 cm. in ballistics gel during impact with medium-velocity pistol projectiles. These results bring into question how much nerve injury is caused via hyperthermic insult versus crush/penetration injury during impact of a sidearm projectile.

The peripheral nerve was embedded 1 cm. into the 10% ballistics gel to simulate in-vivo position of peripheral nerve in upper extremity as was determined by McCartney. They demonstrated that the distance from skin to median nerve throughout the upper extremity (wrist 2.1 mm ± 0.5, distal forearm 8.5 mm ±1.9, middle forearm 12.4 mm ± 2.2, proximal forearm 16.8 mm ± 2.7, and elbow 7.1 mm± 2.7) is an average of 9.4 mm.

For this project, 10% ballistics gel (Clear Ballistics® Fort Smith, AR) at room temperature was used for its similarity to human tissue in the manner which it transmits energy from high-speed projectiles. Increasing the starting temperature of the ballistics gel and nerve segments to normal body temperature would have altered the ballistic characteristics of the gel and would not be similar to that of human tissue.

Given that the projectile was affecting the ballistics gel and nerve as a system and not acting as a direct transferor of thermal energy from the projectile itself, the authors concluded that temperature changes would be constant regardless of the initial temperature of the gel and nerve. Given this information, the authors addressed the average maximum temperature adjustment by increasing normal body temperature of 37°C by 26.4°C to give an adjusted value of 63.4°C ± 3.2, 95% CI [57.2 – 72.4°C].

There have been several studies describing how thermal energy may propagate nerve damage in the pertinent literature. Hoogeveen et al described how exposing peripheral nerves, utilizing an in-vivo rat model, to a heat source of 45°C for 30 minutes led to gradual decreases of motor and sensory function with complete loss to both at seven hours post heat exposure. This group reported that it had required four hours post hyperthermia insult to visualize swelling of the media, loosening of the adventitia, perivascular edema, and disruption of myelin sheaths of nerve tissue seen on histological slides.
Xu and Pollock\(^8\) demonstrated with an in-vivo rat model that exposing sciatic nerve tissue to low grade temperatures of 47°C correlated with a delayed and irreversible block to A-fibers (myelinated) conduction. Immediately after sciatic nerves were exposed to a heat source, there was no observable change to the nerve tissue structure under light microscopy. This is in contrast to the advanced nerve tissue degeneration which was viewed six hours post low-grade heating. One day after this low-grade hyperthermic injury, nerve fibers demonstrated damage that extended distal to the heated nerve segment.

Xu and Pollock\(^8\) also exposed a number of sciatic nerves to high-grade temperatures of 58°C. Immediately after the high-grade heat exposure, the myelinated fibers appeared normal overall under light microscopy. However, three days post high-grade thermal exposure, the nerve tissue demonstrated global destruction of both the myelinated and unmyelinated nerve fibers.

Lynch and Pollock\(^9\) described how necrosis of nerve tissue was propagated by ischemia after hyperthermic insult due to the sensitivity of the vasa nervorum to variations in temperature leading to the process of heat-induced angiopathy.

The time lag between the hyperthermic insult and progression of symptoms and histological changes in the authors’ study may explain why there was no discernable injury seen with our nerve samples post-projectile impact and hyperthermic exposure. Further research utilizing an in-vivo model, where a nerve tissue is rapidly heated 26.4°C above baseline followed by serial physical and histological examination similar to prior studies may have provided a fuller account of how nerve tissue can be injured during impact with a medium-velocity projectile.

Our findings suggest that nerve injury after pistol projectile collision may be secondary to nerve necrosis from heat induced angiopathy in addition to the classic model of concussion and penetration. More importantly, thermal injury to peripheral nerves from pistol projectiles may not be immediately apparent on physical exam as nerve necrosis from heat-induced angiopathy may be delayed.

**Limitations**

One of the major limitations to this study, on a histology basis, was the use of fresh frozen cadaver nerves for our tissue samples. The use of in-vivo tissues would have been
ideal for monitoring the progression of tissue destruction after hyperthermic injury. The 10% ballistics gel used was an average of $28.8^\circ C \pm 0.6^\circ C$, 95% CI [26.4-30.3$^\circ C$] at baseline. Elevating the temperature of the ballistics gel might have provided a more accurate estimate of occurring temperature changes under physiological conditions. However, this would have also changed the ballistic characteristics of the gel by losing its similarity to human tissue. A second limitation of the study was that we were not able to record the length of time temperatures were maintained after impact due to limitations of our computer processing power.

CONCLUSIONS

In summary, the authors were able to observe and record how much thermal energy was released into nerve tissue embedded 1 cm. in a substance similar to human tissue during impact with medium-velocity pistol projectiles. Our adjusted average maximum temperatures ($63.4^\circ C \pm 3.2$, 95% CI [57.2 – 72.4$^\circ C$]) were higher than those previously reported to cause delayed heat induced necrosis.$^8,^9,^{12}$ These findings bring into question how much nerve injury is caused via hyperthermic insult versus crush/penetration injury during impact of a pistol projectile. When dealing with patients who have sustained gunshot injuries in close proximity to peripheral nerves, providers should be mindful that nerve injury may result from the generated heat during impact through a delayed process that may not be immediately observable on initial physical exam.$^8,^9,^{12}$

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3. Underwood Ammunition® for donating ammunition.
4. FLIR Research® for allowing us use of their X6901sc camera and software.
REFERENCES


**TABLES AND FIGURES**

**Figure 1:**
Position of IR Camera Placement Relative to the Ballistics Gel *

<table>
<thead>
<tr>
<th>Shooter located behind ballistic barrier</th>
<th>Electronic digital chronograph</th>
<th>10% Ballistics gel block</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-speed infrared camera</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* The shooter for this experiment was located to the left of the camera behind the ballistic shield. This setup was chosen both for the safety of the computer / camera operator and to give us access to the impact side of the ballistics gel for analysis.
Figure 2: IR Signal of the Peripheral Neve Impregnated Ballistics Gel Immediately During Impact with the 9 mm. NATO-Classified Pistol Projectile*

* The color scale, in relation to the designated temperature (°C) is located to the right of the image. We used the inner most aspect of the shock wave to calculate internal temperature in ° Celsius.
Figure 3:
Maximum Temperatures (°C) of the Projectile and Peripheral Nerve Impregnated Ballistics Gel Before, During and After Impact
### Table 1: Maximum Temperatures of Projectile Impacts *

<table>
<thead>
<tr>
<th>Nerve Trial</th>
<th>Max Bullet Temperature (°C)</th>
<th>Ballistic Gel Temperature (°C)</th>
<th>Max Entry Temperature (°C)</th>
<th>Change in Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nerve 1</td>
<td>33.1</td>
<td>29.6</td>
<td>51.5</td>
<td>21.9</td>
</tr>
<tr>
<td>Nerve 2</td>
<td>33.5</td>
<td>29.7</td>
<td>53.8</td>
<td>24.1</td>
</tr>
<tr>
<td>Nerve 3</td>
<td>33.9</td>
<td>29.9</td>
<td>51.3</td>
<td>23.2</td>
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<td>Nerve 4</td>
<td>32.7</td>
<td>26.7</td>
<td>62.1</td>
<td>35.4</td>
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<tr>
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<td>31.9</td>
<td>26.4</td>
<td>57.9</td>
<td>31.5</td>
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<td>32.0</td>
<td>26.4</td>
<td>61.0</td>
<td>34.6</td>
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<tr>
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<td>33.0</td>
<td>30.1</td>
<td>50.3</td>
<td>20.2</td>
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<td>Nerve 8</td>
<td>32.9</td>
<td>30.2</td>
<td>53.0</td>
<td>22.8</td>
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<td>35.5</td>
<td>30.3</td>
<td>56.4</td>
<td>26.1</td>
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<td>Nerve 10</td>
<td>32.4</td>
<td>27.8</td>
<td>57.5</td>
<td>29.7</td>
</tr>
<tr>
<td>Nerve 11</td>
<td>32.9</td>
<td>29.9</td>
<td>51.5</td>
<td>21.6</td>
</tr>
</tbody>
</table>

* All calculations were done with confidence interval of 0.1.