The MSPress Journal

Vol 10 | No. 1 | 2023

Examination of Unilateral, Partial Rectus Abdominis Absence in a Cadaver Dissection

Kathryn Hall[1], Erika Anaya[1]

1. Burrell College of Osteopathic Medicine, Las Cruces, NM

Abstract: A team of medical student researchers encountered a human cadaver specimen during a structured dissection program that presented with a partially absent right rectus abdominis. Without a medical history of known trauma nor peripheral neurological compromise, this team began researching for potential causes of such a specific and localized loss of normal muscle anatomy. Later discovery of a missing gallbladder and metal staple in the remains of a cystic duct, led this team to conclude thoracic spinal nerve injury during a cholecystectomy likely led to ipsilateral rectus abdominis atrophy. The possibility of muscle atrophy from nerve damage during laparoscopic cholecystectomy bears further investigation due to the overwhelming popularity of the approach.

Keywords: Rectus Abdominis, Abdominal Muscle Atrophy; Spinal Nerve T6-T11 Muscle Innervation, Cholecystectomy

---

Introduction:

More than one million cholecystectomies are performed annually in the United States and it was one of the first procedures to be routinely performed using robotic assistance during laparoscopy [1]. However, the potential for secondary nerve damage during the procedure has yet to be fully examined. This cadaveric dissection case reviews the possible role laparoscopic cholecystectomies could play in the unilateral partial atrophy of the rectus abdominis (RA) muscle due to spinal nerve disruption.

Background:

The abdominal region serves many functions and consists of many parts that work together. The skin is the most superficial layer. The thickness of the skin is roughly 2.20-28.05 mm in males and 5.15-27.40 mm in females [2]. This layer is followed by fat and fascia. Deep to the fascia are the various muscle layers. The rectus abdominis muscle is found at the midline, where it spans inferiorly from the xiphoid process and level of the 5th to 7th ribs to the superior crest of the pubis. This muscle assists in abdominal flexion and stabilizes the pelvis [3]. The muscle contains tendinous intersections that make the “six-pack” appearance. It is innervated by intercostal nerves (T5-T11) and subcostal nerves (T12) [3]. These nerves can be injured and if disrupted could potentially cause muscle atrophy of the rectus abdominis. The RA is medially joined together by the linea alba and extends laterally to the semilunar line. The main arterial supply to the rectus abdominus muscle is from the inferior epigastric artery which is a direct branch of the external iliac artery. Overall, the abdominal wall serves to protect our peritoneum and internal organs.

Shifting focus to the liver and gallbladder; the liver is located in the right upper quadrant of the abdomen and weighs approximately three pounds [4]. It sits inferior to the diaphragm and protected by the ribs. The liver has many functions including but not limited to the following: producing proteins, cholesterol, and bile, detoxifying the blood and regulating blood clotting. Just inferior to the liver, the gallbladder works in conjunction with the liver. Together these two organs provide bile acids into the small intestine where they aid in digestion of fats. Liver cells secrete bile that is collected by several ducts that flow through the liver and drain into the gallbladder. The main function of the gallbladder is to store bile acids until signaled to release them [5].

The gallbladder is the culprit of many pathological problems, many of which require a cholecystectomy. A cholecystectomy is a common surgery in the United States and carries only a small risk. The surgery can be performed using an open or laparoscopic approach, the latter of which is becoming the more common approach. With a laparoscopic cholecystectomy, the surgeon uses a scalpel to make four incisions about two inches in length and inflates the abdomen with carbon dioxide to help with visualization. A video camera is inserted into the abdomen through one of the incisions. The surgeon watches the video on a monitor and proceeds with the removal of the gallbladder. The surgeon uses tools to isolate the gallbladder from the liver and surrounding structures. The surgeon must be careful to avoid potentially dangerous arteries and nerves that can lead to significant damage. Once the gallbladder is fully isolated the surgeon will clip the stalk of the gallbladder with two metal clips and will release the gallbladder. The open surgical approach is more invasive due to having a larger incision in the abdominal wall. The surgeon makes an approximate 6-inch incision on the abdomen below the ribs on the right side [6]. The skin, fat, and muscle will be pulled back to better visualize the gallbladder. Once it is visible it can be removed using the same manner. Upon completion of either procedure the incisions are sutured, and the patient is taken to a recovery room.

Case

The provided cadaver was an 88-year-old male whose previous occupational history included work as a security guard. The complete past medical history for the donor was not retained following donation. However, the following conditions were noted in the donation chart; atrial fibrillation and ischemic cardiomyopathy with a positive history of myocardial infarction. Other diagnoses included hypertension, coronary artery disease, and chronic kidney disease. No surgical history was provided.

This human cadaver dissection was undertaken as part of a six-week Directed Anatomical Dissection Program at the Burrell College of Osteopathic Medicine from May 2021- July 2021. Student dissectors were supervised by professors throughout the experience. All dissection cuts were made with either straight surgical scissors or a size 10 surgical scalpel blade. All measurements were recorded in millimeters using a measuring tape. The dissection and reflection of the abdominal wall were completed following the approaches as outlined in Grant's Dissector [7] (pp.110-112).

The team started with an inspection of the abdomen and chest wall. No scars, abnormal pigments, or signs of trauma were noted. The team proceeded with an abdominal wall reflection approach which gave an optimal view of the rectus abdominis muscle but also used methods of the four abdominal quadrants approach as well. The dissection began with an incision along the costal margin through the anterolateral abdominal wall continuing laterally towards the mid-axillary line. Next, a cut was made through the posterior rectus sheath superiorly to release the anterior abdominal wall from the costal margin and xiphoid process. This was followed by a vertical cut through the linea alba at the start of the xiphoid process extending inferiorly towards the pubic symphysis. The abdominal wall was separated from the abdominal contents by peeling back the musculature and sliding tools between the layers. Upon opening the thoracic and abdominal cavities, superficial anatomical structures (except the RA) were identified in the anticipated locations with normal presentations.

For the dissection of the liver and gallbladder, the fascia and musculature of the abdominal cavity were reflected and the liver's attachment to the falciform ligament was cut through to free the liver from its anterior anchor point [7]. The separation of the liver from the rest of the anchoring fascia was completed by inserting and sliding a hand between the organ and the body cavity wall. In-cavity manipulation of the liver was then possible to allow progress toward the identification of the gallbladder, or in this case lack thereof.

Grant's Dissector directed the dissection team to search for the gallbladder along the midclavicular line in the region of the ninth costal cartilage [7]. The dissection team found no gallbladder present. Instead, the team identified the remnants of the cystic duct that had closed by obvious primary intention given the presence of a staple within it. The donor had an undisclosed cholecystectomy.

Discussion

In a study of 75 adult males, average ultrasound thickness of the rectus abdominis (RA) muscle between 10.3-10.4mm [8]. This contrasts with the 7mm measured thickness of the left RA and the 1-2mm measurement of the right RA. It is appreciated during the preparation of bodies donated to science, preservative practices will impact tissue density and therefore thickness measurements. A difference of almost nine millimeters is more than anticipated. A 5mm difference left to right is also unexpected. The brief medical history provided of the donor did not include any mention of surgical interventions or muscular degenerative diagnoses. As such, these researchers began investigating for a source of the donor's unilateral, partial absence of the right RA.

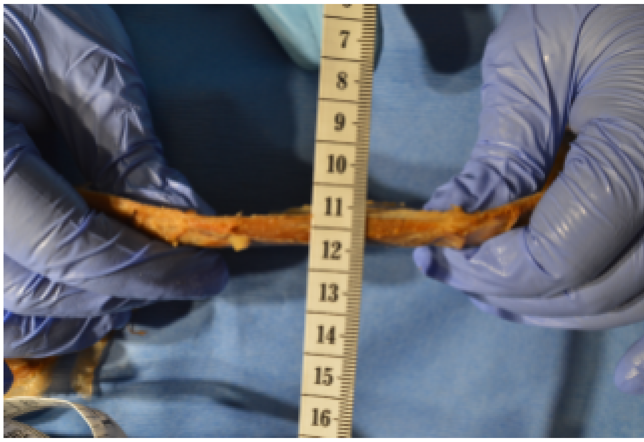

Figure 1. 7mm thickness of left (unaffected) RA

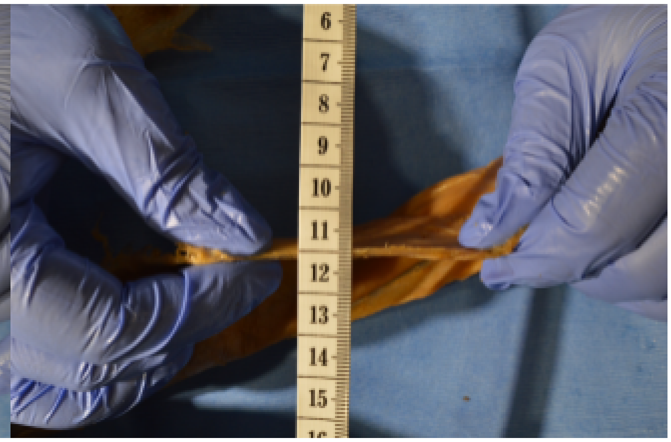

Figure 2. 1-2mm thickness of right (affected) RA

The initial investigation was directed at congenital or genetic abnormalities. Financial and logistical limitations of the directed dissection program did not allow for definitive genetic testing. Diagnoses were excluded based on noncompliance of the donor's presentation with syndromes' criteria. Prune Belly Syndrome is a congenital agenesis of the RA and/or other abdominal musculature [9]. Prune Belly also includes skeletal anomalies in the ribs and vertebrae. Neither were present in this specimen. Another endogenous explanation was embryological damage. Sixth-week embryological damage would account for a complete absence of one RA [10]. However, the most distal aspect of the right RA was present. Genetic damage during development would not result in partial agenesis. The age of the donor and intact remainder of his musculature excluded other genetic causes such as Duchene's Muscular Dystrophy [11].

The investigation then focused on metabolic irregularities. Men with Metabolic Disorder have been found to have thinner RA muscles, with greater thinning occurring as the severity of the disease progresses [12]. The mechanism of metabolic disorder related loss of muscle mass remains unknown. However, studies describe a consistent loss across the whole of the abdominal musculature, not a unilateral affection by the disease on a single muscle. Despite lacking the donor's entire medical history, this team agrees that an unspecified metabolic disorder(s) would not account for the localized presentation of the muscle loss.

It has been shown that ipsilateral RA muscle atrophy may occur following robotic thoracic surgery due to possible injury of local neuroanatomy [13]. The lack of obvious scarring present on this cadaver's skin, it would be more logical to conclude this procedure had been accomplished via robotic laparoscopy rather than an open surgical approach. Robotic laparoscopic cholecystectomies have largely replaced open procedures, but are not without risks. One retrospective analysis found as many as 13% of laparoscopic cholecystectomy patients experience intraoperative complications [14].

Postoperatively, complications with pain are frequent and often result from lingering gastrointestinal problems. However, intercostal neuroma pain has been found to cause significant discomfort for some patients. This discomfort has been attributed to the disruption of the local neuroanatomy, specifically the intercostal nerves [15].

The RA's neuronal innervation stems from the intercostal nerves and the T7-T11 spinal nerves on each side [16]. Surgical interventions in the thorax can interfere with the track a nerve takes to the muscle it innervates, ultimately compromising the function of the neuron's ability to excite a muscle contraction. Chronic postoperative pain following cholecystectomy has been well documented and is commonly attributed to affected T6-T8 spinal nerves [17]. Without consistent stimulation, skeletal muscle atrophies [18]. Spinal nerve injury during a robotic laparoscopic cholecystectomy would allow the ipsilateral partial atrophy of the donor's right RA. Verification through individual spinal nerve dissection was not possible during the accelerated program schedule and the anterior rib cage was subsequently removed entirely during the dissection of the chest cavity. The authors recognize that as a limitation in this case study.

Conclusions

The rampant popularity of robotic laparoscopic cholecystectomies worldwide means awareness must be paid to the possible side effects. Incisions into the abdominal muscle wall and manipulation of laparoscopic instruments through those openings carry the potential for unintended disruption of spinal nerves. The incidence of laparoscopic cholecystectomy procedures damaging spinal nerves bears further review. These authors would suggest a retrospective study with RA depth ultrasound measurements following robot assisted laparoscopic cholecystectomy patients for months and years postoperatively to determine if muscle atrophy is experienced.

Acknowledgments:

This research was supported by Burrell College of Osteopathic Medicine, which provided the necessary materials and the opportunity to conduct this paper. We are immensely grateful to the Anatomical Gifts Program which works with medical schools to provide first-hand anatomical education through cadavers that are made possible through the selfless acts of persons who donate their bodies to science. We would like to also thank Dr. Bonny Ford, Ph.D., and Dr. Jon Jackson, Ph.D. for their exceptional anatomy expertise and invaluable guidance while writing this paper. Lastly, thanks go out to Mr. Kevin Watson for his assistance during the dissection and photography of the specimen to use in this write-up.

Conflicts of Interest: The authors declare that there are no conflicts of interest to disclose.

References

1. Shenoy, R., Mederos, M.A., Ye, L. et al. Intraoperative and postoperative outcomes of robot-assisted cholecystectomy: a systematic review. Syst Rev 10, 124 (2021). https://doi.org/10.1186/s13643-021-01673-x
2. Jain, S. M., Pandey, K., Lahoti, A., & Rao, P. K. (2013). Evaluation of skin and subcutaneous tissue thickness at insulin injection sites in Indian, insulin naïve, type-2 diabetic adult population. *Indian journal of endocrinology and metabolism*, *17*(5), 864–870. https://doi.org/10.4103/2230-8210.117249
3. Gilroy, A. M., MacPherson, B. R., Schünke Michael, Schulte, E., Schumacher, U., Voll, M., & Wesker, K. (2016). *Atlas of anatomy* (third). Thieme.
4. Liver:Anatomyandfunctions.JohnHopkinsMedicine.RetrievedFromHttps://www.hopkinsmedicine.org/health/conditions-and-diseases/liver-anatomy-and-functions
5. Biliary system anatomy and functions. Johns Hopkins Medicine. (n.d.). Retrieved January 13, 2022, from https://www.hopkinsmedicine.org/health/conditions-and-diseases/biliary-system-anatomy-and-functions
6. Mayo Foundation for medical education and research. . (2021, September 18). Cholecystectomy (gallbladder removal). Mayo Clinic. Retrieved January 13, 2022, from https://www.mayoclinic.org/tests-procedures/cholecystectomy/about/pac-20384818
7. Detton AJ. “Chapter 4 The Abdomen.” Grant’s Dissector, 16th ed., Lippincott, Williams & Wilkins, Baltimore, MD, 2016, pp. 110-112, 120-122.
8. Tahan, N., Khademi-Kalantari, K., Mohseni-Bandpei, M.A. et al. Measurement of superficial and deep abdominal muscle thickness: an ultrasonography study. J Physiol Anthropol 35, 17 (2016). https://doi.org/10.1186/s40101-016-0106-6
9. Gerard-Blanluet M, Port-Lis M, Baumann C, Perrin-Sabourin L, Ebrad P, Audry G, Verloes A. 2010. Unilateral agenesis of the abdominal wall musculature: An early muscle deficiency. Am J Med Genet Part A 152A:2870–2874.
10. Shanmugam S, Thiagarajam S, Jayamurugavel G. Unilateral Partial Absence of Rectus Abdominis Muscles. International Journal of Anatomical Variations. 88-90 (2016). https://www.pulsus.com/scholarly-articles/unilateral-partial-absence-of-rectus-abdominis-muscle.pdf

11. Hooijmans MT, Niks EH, Burakiewicz J, Anastasopoulos C, van den Berg SI, van Zwet E, Webb AG, Verschuuren JJGM, Kan HE. Non-uniform muscle fat replacement along the proximodistal axis in Duchenne muscular dystrophy. Neuromuscul Disord. 2017 May;27(5):458-464. doi: 10.1016/j.nmd.2017.02.009. Epub 2017 Feb 21. PMID: 28302391.
12. Choi ES, Cho SH, Kim J-H (2017) Relationship between rectus abdominis muscle thickness and metabolic syndrome in middle-aged men. PLoS ONE 12(9): e0185040. https://doi.org/10.1371/journal.pone.0185040
13. Wang Y, Bhandari P, Trope B, Berry M, Shrager J, Lui N. Greater Ipsilateral Rectus Muscle Atrophy After Robotic Thoracic Surgery Compared to Open and VATS Approaches. Thoracic Surgery. 2020 October; 231(4). DOI: https://doi.org/10.1016/j.jamcollsurg.2020.07.425.
14. Radunovic, M., Lazovic, R., Popovic, N., Magdelinic, M., Bulajic, M., Radunovic, L., Vukovic, M., & Radunovic, M. (2016). Complications of Laparoscopic Cholecystectomy: Our Experience from a Retrospective Analysis. Open access Macedonian journal of medical sciences, 4(4), 641–646. https://doi.org/10.3889/oamjms.2016.128
15. Dellon AL. Intercostal neuroma pain after laparoscopic cholecystectomy: diagnosis and treatment. Plast Reconstr Surg. 2014 Mar;133(3):718-721. doi: 10.1097/PRS.0000000000000065. PMID: 24572861.
16. Jelinek LA, Scharbach S, Kashyap S, et al. Anatomy, Abdomen and Pelvis, Anterolateral Abdominal Wall Fascia. [Updated 2020 Oct 30]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK459392/
17. Cholecystectomy leading to pain from nerve compromises in T6-T8. Dellon AL. Intercostal neuroma pain after laparoscopic cholecystectomy: diagnosis and treatment. Plast Reconstr Surg. 2014 Mar;133(3):718-721. doi: 10.1097/PRS.0000000000000065. PMID: 24572861.
18. Cisterna BA, Cardozo C, Sáez JC. Neuronal involvement in muscular atrophy. Front Cell Neurosci. 2014;8:405. Published 2014 Dec 10. doi:10.3389/fncel.2014.00405