Published in final edited form as:

J Surg Res. 2011 September ; 170(1): 64–68. doi:10.1016/j.jss.2011.03.005.

Infrared Thermographic Profiles Of Vessel Sealing Devices On Thyroid Parenchyma

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Abstract

Introduction—During thyroid lobectomy, division of the thyroid parenchyma has traditionally been accomplished using suture ligation. Development of hemostatic techniques in the forms of ultrasonic dissection (UD) and electronic vessel sealing (EVS) have increased the usage of these devices during thyroid operations. We sought to characterize the thermal profile of each of these devices when used to divide the parenchyma of the thyroid gland.

Methods—Using a porcine model, the parenchyma of the gland was then sealed by alternating application of the UD and EVS devices. In each case the thermal activity was recorded using infrared thermal imaging. We performed multiple seals with each instrument and then compared the thermal profiles.

Results—There was no significant difference in lateral thermal spread of EVS and UD above 39, 40 or 60 degrees Celsius (2.30 ± 0.31 mm vs. 2.53 ± 0.47 mm, $P=0.26$; 2.22 ± 0.27 mm vs. 2.47 ± 0.47 mm, $P=0.22$; and 1.37 ± 0.27 mm vs. 1.54 ± 0.26 mm, $P=0.22$). There was no significant difference in mean time above 39, or 40 degrees Celsius (35.1 ± 8.7 s vs. 31.7 ± 9.3 s, $p=0.47$ and 29.9 ± 8.1 s vs. 27.3 ± 6.7 s, $p=0.50$). UD reached a greater maximum temperature (179.12 ± 0.0008 C vs. 96.52 ± 5.6 C, $p<0.001$) and stayed over 60 degrees Celcius for longer than EVS (9.5 ± 1.8 s vs. 5.3 ± 0.97 s, $p<0.001$).

Conclusions—The amount of lateral spread of thermal energy was not significantly different between the UD and EVS devices. However, the use of UD produced a higher maximum temperature during thyroid parenchyma sealing and remained above 60 degrees longer than EVS. This may translate into greater thermal injury to thyroid and surrounding tissues during division.

Keywords

LigaSure; Harmonic; Thyroid; Thermal spread; Thermography; Parenchyma; Vessel sealing; Temperature

Introduction

Traditionally thyroid surgery has been performed utilizing suture ligation to achieve hemostasis, with complication rates reported to be 5–15% for transient hypocalcemia and recurrent laryngeal nerve injury and as low as 1% or less for permanent paralysis of the recurrent laryngeal nerve and hypocalcemia [1], [2], [3], [4], [5], [6] and [7]. These complications occur due to the close proximity of the recurrent laryngeal nerves and parathyroid glands to the thyroid tissue [8]. Additionally, up to 14% of patients undergoing

thyroid lobectomy will have hypothyroidism requiring medication [9]. Injury to the remaining thyroid tissue or its blood supply may contribute to this risk. With meticulous dissection and effective hemostasis, both standard total thyroidectomy and thyroid lobectomy are considered safe procedures [3], [10], [11] and [12].

Over the last few years an increasing number of surgeons have begun to use vessel sealing technology in thyroidectomy [13]. The Harmonic Scalpel is a vessel sealing device that uses low frequency ultrasonic energy causing protein denature, ultrasonic dissection (UD), and transform into a new protein shape to seal. The LigaSure utilizes electrical energy and pressure to liquefy and reform the collagen and elastin, electronic vessel sealing (EVS) to provide hemostasis. Multiple studies suggest that it is safe to perform total thyroidectomies and lobectomies with the new vessel sealing devices [2], [3], [8], [14], [15], [16], [17] and [18]. In addition to being used for vessel sealing, it is common for these newer devices to be used for dividing thyroid parenchyma [14] and [16]. By using these devices to divide parenchyma the lateral thermal spread may damage the remaining thyroid tissue contributing to hypothyroidism after lobectomy. We therefore set out to characterize the thermal profiles on thyroid tissue of both UD and electronic vessel sealing (EVS) using two devices which have narrow tips and are well suited for use in thyroidectomy: the Harmonic Focus (Ethicon Endo-Surgery, Cincinnati, OH) and the LigaSure Precise (Covidien, Mansfield, MA).

Materials and Methods

The University of Wisconsin Animal Care and Use Committee approved all experiments. General endotracheal anesthesia was induced in 3 University of Wisconsin, Yorkshire female pigs. The thyroid gland was brought up through a midline neck incision and the thyroid parenchyma was sealed by successive application of each device. When the EVS device was used, tissue was sharply divided using surgical scissors after the seal was complete. The LigaSure was set to 2 bars and the Harmonic was set to 5 (slow). The instrument and tissue were isolated during activation and the thermal activity was recorded using infrared thermal imaging (SC660, Flir Systems Inc.) We performed 8 seals with each instrument and the thermal videos were then analyzed using computer software (ThermoVision ExaminIR, Flir Systems, Boston MA) and data was collected and compared on spatial and temporal temperature profiles of the sealed vessel. Data was compared using a student's T-test with a p-value of <0.05 being statistically significant. Results are reported as mean $\pm$ the standard error of the mean.

Results

Lateral thermal spread is similar for UD and EVS

Lateral thermal spread may place nearby structures and remaining thyroid tissue at risk for injury. We compared the lateral thermal spread of UD and EVS when dividing thyroid parenchyma. Figure 1 shows the width to temperature profile for the two devices. The lateral distance of thermal spread greater than 39 degrees Celsius was not significant between the devices (2.30 ± 0.31 mm vs. 2.53 ± 0.47 mm, $P=0.26$). Distance of thermal spread above 40 degrees did not differ either (2.22 ± 0.27 mm vs. 2.47 ± 0.47 mm, $P=0.22$), nor did thermal spread above 60 degrees between the 2 devices (1.37 ± 0.27 mm vs. 1.54 ± 0.26 mm, $P=0.22$). Averages and standard error are shown in Figure 2. The jaws of the UD device are about 3 mm wide and the jaws of the EVS device are about 4 mm wide. When adjustments were made for thermal spread beyond the edge of the jaws, differences between the two devices were not statistically significant (results not shown).

UD produces higher temperatures and stays hot longer then EVS

In addition to lateral thermal spread, the maximum temperature reached may increase the risk of inadvertent contact injury and the time adjacent tissues remain above physiologic temperatures may contribute to thermal damage. The maximum temperature of each device as well as the cooling profile of the tissue was also measured. Figure 3 shows the temperature versus time profile of each activated device and cooling tissue. There was no significant difference in mean time that tissue remained above 39 degrees Celsius (35.1 ± 8.7 s vs. 31.7 ± 9.3 s, $p=0.47$). There was also no difference in time above 40 degrees (29.9 ± 8.1 s vs. 27.3 ± 6.7 s, $p=0.50$). The maximum temperature of the UD device was statistically significantly higher than EVS (179.12 ± 0.0008 C vs. 96.52 ± 5.6 C, $p<0.001$) and remained above 60 degrees C for longer time than the EVS device (9.5 ± 1.8 s vs. 5.3 ± 0.97 s, $p<0.001$). Averages and standard error are shown in Figure 4.

Discussion

UD and EVS have been used safely in a variety of surgical procedures including hemorrhoidectomy, hysterectomy, laparoscopic colectomies, and esophagectomies [2], [19], [20], [21], [22] and [23]. Their role has also become common in thyroid operations and, although somewhat controversial, there is evidence showing benefits such as reduced operative time, reduced blood loss, and postoperative pain [2], [8], [13], [14], [15], [16], [17], [22], [24] and [25]. However, these new hemostatic techniques involve the use of thermal energy compared to traditional suture ligation. Thermal spread and inadvertent contact may lead to injury to adjacent structures or tissues. A thorough understanding of the temperature profiles of these instruments can assist the surgeon in minimizing the risk of harm.

Although several researchers have compared the lateral thermal spread of these devices when used for vessel sealing and division of abdominal tissues, we are not aware of any that compare the profiles for sealing thyroid parenchyma [26], [27], [28], [29] and [30]. UD uses low frequency ultrasonic energy causing protein denature and transform into a new protein shape to seal vessels and tissues up to 5-mm thick, leading to coagulation while EVS utilizes both electrical energy and pressure to liquefy and reform the collagen and elastin in vessel walls and tissue up to 7 mm in diameter to provide hemostasis [31] and [32]. Because the mechanism is fundamentally different it is important to examine the potentially different effects each may have on tissues. Different tissues are made of varying protein and collagen compositions and may react differently to these new devices.

Previous reports have shown lateral spread between the UD and EVS devices to be of similar magnitude, but none specifically address these small devices. These studies utilized laparoscopic instruments which precede those tested here (primarily the Harmonic A.C.E. or LigaSure V). Pathologic examination demonstrated lateral spread on the order of 0–3.5 mm for UD devices and 2.5–5.8 mm for EVS devices [26], [28] and [30]. Each of these studies predated a newer generator for EVS (ForceTriad, Covidien, Boulder, CO). This may explain the greater spread reported for EVS. A study done by Phillips and colleagues reported the lateral spread data on various abdominal tissues (ureter, bladder, small bowel, and colon) and showed similar lateral spread for all tissues except the ureter, in which EVS had significantly greater lateral spread [30]. This is similar to our results, which demonstrate no difference in the lateral spread between the UD and EVS devices when used on thyroid tissue.

When looking at the maximum temperatures reached by UD and EVS, we found that the UD device achieved a maximum temperature that was nearly double that of the EVS device. The UD instrument also remained at a temperature above 60 degrees Celsius for a significantly

longer time period than the EVS device. This is consistent with a study by Kim et. al. utilizing the laparoscopic UD and EVS instruments. They found that the UD device reached temperatures above 200 C while the EVS instrument was consistently below 100 C and the UD took twice as long to cool [27].

There are limitations to this study. The number of observations is low and our results may represent insufficient power to detect a difference between the two devices. We were unable to demonstrate a difference in lateral thermal spread between these two devices. Given the amount of lateral spread, which was seen we believe the potential differences are too small to be clinically significant. Also, although we were able to demonstrate a difference in maximum temperature reached, thermal imaging is only able to display surface temperatures and no measure was possible of temperatures deep to the surface. The cut off values of 39, 40 and 60 are somewhat arbitrary and represent physiologic temperature, near physiologic temperature, and damaging temperature respectively.

Conclusion

In summary there were no significant differences in the distance of lateral thermal spread between the devices. The UD device became hotter and produced temperatures over 60 degrees for a longer period of time than the EVS device. The two devices affect similar amounts of tissue, which suggests similar risk of thermal injury to surrounding structures during vessel sealing. However, use of the harmonic scalpel requires extra attention due to its higher temperatures.

Acknowledgments

This study was funded, in part, by NIH T32 Training Grant-CA090217. We would like to thank Kim Maurer for her assistance in this project.

Disclosure: This study was funded by Covidien, who manufactures the LigaSure Precise device.

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Figure 1. Lateral thermal profile of the UD and EVS devices

Distances are in millimeters. Zero represents the center of the jaws on each device. There was no significant difference in the width of thermal spread above 39, 40 or 60 degrees Celsius.

Figure 2. Averages and standard error of the lateral thermal spread of UD and EVS

Distances are in millimeters. Width of lateral thermal spread was not statistically different at 39, 40 or 60 degrees Celsius (2.30 ± 0.31 mm vs. 2.53 ± 0.47 mm, $P=0.26$; 2.22 ± 0.27 mm vs. 2.47 ± 0.47 mm, $P=0.22$; and 1.37 ± 0.27 mm vs. 1.54 ± 0.26 mm, $P=0.22$; $n=8$).

Figure 3. Maximum temperature curves for UD and EVS versus time

Time is given in seconds. There was no significant difference in mean time above 39, or 40 degrees Celsius. The UD device reached a higher maximum temperature and stayed above 60 degrees C longer than the EVS.

Figure 4. Averages and standard error of the time above threshold and maximum temperature of UD and EVS

Time is given in seconds. Mean time above 39 or 40 degrees Celsius was not statistically significantly different (35.1 ± 8.7 s vs. 31.7 ± 9.3 s, $p=0.47$ and 29.9 ± 8.1 s vs. 27.3 ± 6.7 s, $p=0.50$). The maximum temperature of the UD device was statistically significantly higher (179.12 ± 0.0008 C vs. 96.52 ± 5.6 C, $p<0.001$) and stayed over 60 degrees C for longer time than the EVS device (9.5 ± 1.8 s vs. 5.3 ± 0.97 s, $p<0.001$; $n=8$).