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CONTROLLED PROSPECTIVE CLINICAL TRIALS

Minimally invasive video-assisted thyreoidectomy (MIVAT) with and without use of harmonic scalpel—a randomized study

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Abstract
Background and aims Minimally invasive video-assisted thyroidectomy (MIVAT) has been used for the removal of small thyroid nodules to improve cosmetic results and diminish pain. The aim of this study was to compare the outcomes of the MIVAT operations with and without the use of an ultrasonic harmonic scalpel (HS).
Patients and methods Seventy-six patients with a solitary thyroid nodule below 30 mm in diameter were randomized to two groups of 38 patients each. Unilateral thyroid lobectomy was performed in each patient. In the clip-ligation group (CL-G), during MIVAT, the superior thyroid vessels were clipped and bipolar coagulation was used to secure smaller vessels, whereas in the harmonic scalpel group (HS-G), HS was used to dissect and divide all the thyroid vessels. The statistical analysis included the mean operative time, blood loss, postoperative morbidity, scar length, cosmetic satisfaction at 1 and 6 months following surgery, and cost-effectiveness.
Results HS-G vs CL-G operations were shorter (31.4±7.7 vs 47.5±13.2 min; $p<0.001$), the mean blood loss was smaller (12.9±5.7 vs 32.8±13.0 ml; $p<0.001$), the mean scar length at 1 month following surgery was shorter (15.6±1.4 vs 21.5±1.9 mm; $p<0.001$), and greater cosmetic satisfaction was achieved at 1 month after surgery (88.9±9.7 vs 81.9±5.4 pts; $p<0.001$), but the difference became nonsignificant at 6 months postoperatively. MIVAT with HS was 20–30 euros more expensive. No major complications were observed in both groups.
Conclusions HS in the MIVAT operations is safe and facilitates dissection, allowing for a significant decrease in operative time. Other benefits, such as lower blood loss, a scar a few millimeters shorter, or a slightly better early cosmetic result, are offered at slightly increased costs.

Keywords Minimally invasive video-assisted thyroidectomy · Harmonic scalpel · Ultrasonic shears

Introduction

Thyroidectomy is one of the most common operations performed in endocrine surgery. The pioneers of thyroid surgery, Theodor Kocher and Theodor Billroth, developed an acceptable technique of standardized thyroid surgery between the years 1873 and 1883. In 1907, William Halsted advocated the preservation of parathyroid glands to avoid life-threatening tetany. In 1938, Lahey from Boston reported a significantly lower incidence of recurrent laryngeal nerve injuries following thyroidectomy with the exposure of the nerves as compared to operations without nerve identification. The basic principles of safe and efficient thyroid surgery established in the early twentieth century have remained unchanged, with only a few minor refinements to the technique [1].

The rapid development of laparoscopic surgery in the 1990s led to the development of endoscopic techniques for parathyroid surgery. A significant improvement in endoscopic instrumentation has allowed for the development of other minimally invasive operations for other cervical

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structures. Multiple endoscopic approaches for thyroid excision have been developed, ranging from a gasless, video-assisted central or lateral approach to a complete endoscopic supraclavicular, axillary, anterior chest wall or breast approach [2]. Among all these new operations, minimally invasive video-assisted thyroidectomy (MIVAT), described in 1998 by Miccoli, has gained an increasing popularity in Europe in the last decade [3]. It is safe and offers improved outcomes of surgery in terms of decreased postoperative pain, a shorter scar, and greater cosmetic satisfaction when compared to conventional thyroidectomy [4]. In experienced hands, it is suitable not only for removal of small and benign unilateral thyroid nodules but also for more demanding operations, such as total thyroidectomy for Grave's disease or low-risk thyroid cancer [5, 6]. To facilitate dissection and improve hemostasis during MIVAT operations, the use of the harmonic scalpel (HS), well known from advanced laparoscopic operations, was suggested by Miccoli et al. in 2002 [7]. This tool simultaneously cuts and coagulates by converting electric energy into ultrasonic mechanical high-frequency vibrations, allowing for reliable, safe, and rapid hemostasis and division of tissues [8]. It was demonstrated in a prospective nonrandomized study by Miccoli that the use of HS decreased the operating time needed for both the unilateral MIVAT lobectomy and total thyroidectomy [7]. Few other randomized studies were published reporting significant reduction in operating time of conventional thyroidectomy in operations performed by a surgeon using HS instead of the conventional clip-ligature technique [9–13]. However, to the best of our knowledge, no randomized study has been published in the English literature comparing the outcomes of the MIVAT operations performed with HS vs those without HS, which became the aim of our study. The primary endpoint of this study was the operating time, whereas the secondary endpoints included blood loss, complications, the length of the scar, patients' cosmetic satisfaction, and cost-effectiveness.

Materials and methods

Study design and patient selection

Two thousand eight patients were referred to the Department of Endocrine Surgery, Third Chair of General Surgery, Jagiellonian University College of Medicine in Kraków, Poland, for thyroid surgery between January 2006 and December 2007. Of this group, 109 patients, who were considered for unilateral thyroid lobectomy, underwent office high-resolution Doppler ultrasound of the neck with both 7.5- and 12-MHz linear array transducers (Logiq 7; GE, Solingen, Germany) performed by a single endocrine surgeon (MB) with evaluation of the thyroid volume, distribution, and measurements of thyroid nodules. Finally, 76 patients eligible for MIVAT were included in the study. They signed the informed consent form and were randomized with the sealed envelope method (1:1) to two equal-sized (n=38) groups. The eligibility criteria for MIVAT included a solitary thyroid nodule below 30 mm in maximum diameter, absence of both echographic and biochemical signs of thyroiditis, thyroid volume below 20 ml, no previous neck surgery or neck irradiation, and no suspicion of thyroid malignancy in a fine-needle aspiration biopsy (FNAB) report. The characteristics of the two groups of patients who underwent MIVAT with harmonic scalpel (HS-G) and without harmonic scalpel [clip-ligation group (CL-G)] are presented in Table 1. The inclusion criteria consisted of thyroid pathology qualified for first-time unilateral thyroid lobectomy using the MIVAT technique. The exclusion criteria included previous thyroid or parathyroid surgery, bilateral thyroid disease, thyroid volume higher than 20 ml, FNAB report suspicious for thyroid cancer, irradiation in history, thyroiditis, preoperatively diagnosed recurrent laryngeal nerve palsy, pregnancy or lactation, age below 18 years, high-risk patients (American Society of Anesthesiology 4 grade), and inability to comply with the scheduled follow-up protocol.

Table 1 Characteristics of the two groups of patients who underwent MIVAT with (HS-G) and without (CL-G) ultrasonic HS

	HS-G	CL-G	p value
Sex (male/female)	5/33	4/34	0.72[a]
Age (years)	40.1±7.3	42.1±7.6	0.23[b]
Maximum diameter of the lesion (mm)	19.7±7.0 (10–30)	18.8±(10–30)	0.37[b]
Thyroid volume (ml)	14.5±4.3	14.9±3.9	0.44[b]
Preoperative diagnosis			
Follicular tumor	23	24	0.81[a]
Toxic adenoma	15	14	0.81[a]
Right/left thyroid lobe lesion	20/18	18/20	0.64[a]

Values represent mean±SD unless otherwise indicated.

[a] χ^2 test

[b] t test

In HS-G, a 5-mm Ultrasonic Harmonic Scalpel CS-14C (Ethicon Endo-Surgery, Cincinnati, OH, USA) was used for dissection and to achieve hemostasis, whereas in CL-G the standard surgical clip-ligation technique for major vessels and bipolar coagulation of minor vessels were used during the MIVAT lobectomy. The patients were blinded to the relevant group assignment. The primary endpoint of the study was the operating time, whereas the secondary endpoints included blood loss, complications, length of the scar, patients' cosmetic satisfaction, and cost-effectiveness. The study was approved by the Bioethics Committee of the Jagiellonian University.

Randomization

Randomization was performed by computer and sequencing was based on permuted blocks of three and two to balance the number of patients in the treatment groups. Patients were randomly allocated to one of the treatment groups in a 1:1 ratio. Information on the IONM use remained in consecutively numbered and sealed envelopes that were stored in a specific box in the operating theater. An envelope containing the allocation was added to the patient's file once he/she had entered the operating room. In this way, the patient was blinded to the relevant group assignment. Then, an envelope was opened and the surgeon performed the assigned intervention.

Anesthesia

All the MIVAT procedures were performed under general anesthesia. Two anesthesiologists involved in the study followed a strict protocol including premedication with IV midazolam and anesthesia induction with fentanyl, thiopental, and pancuronium at the body mass-dependent dose. After the endotracheal intubation, all the patients were put on mechanical ventilation (sevoflurane and oxygen mixture). In the course of the operation, all the patients received an IV infusion of Ringer's solution (15 ml/kg). To prevent postoperative vomiting, IV metoclopramide was administered prior to awakening.

Surgical technique

All the operations consisted of the MIVAT unilateral thyroid lobectomy and were performed by the same experienced endocrine surgeons involved in the study (MB, AK, SC). Each of the surgeons involved in this study performed a comparable number of MIVAT operations in each group (12–13 operations in each group). The MIVAT procedure was performed according to the Miccoli technique, with a 1.5-cm horizontal skin incision 2 cm above the sternal notch. As the strap muscles in midline have been dissected but not divided, a working space was created by a blunt dissection with a tiny spatula and retraction of the strap muscles laterally to mobilize the thyroid lobe. The gasless video-assisted approach employing 5-mm 30° rigid endoscope and other instruments designed for parathyroid and thyroid surgery (Karl-Storz, Tutlingen, Germany) was used. The optical magnification allowed for excellent visualization of the external branch of the superior laryngeal nerve and the recurrent laryngeal nerve, which were dissected together with the upper parathyroid gland. The vessels of the upper thyroid pole were dissected and divided with the HS (HS-G) or were double clipped (CL-G) and cut until the lobe was completely freed and could be extracted by gently puling it out through the skin incision. The isthmus was then dissected and divided, followed by dissection and division of the inferior thyroid pole vessels using the HS or a 5-mm clip applier and bipolar coagulation (in HS-G vs CL-G, respectively). After the final check of the recurrent laryngeal nerve, the lobe was removed and referred to histopathology. The strap muscles were approximated using one stitch and the skin incision was closed with a continuous nonabsorbable monofilament suture (prolene 3–0), removed as a routine on the second postoperative day, and replaced by Steri-strips adhesive tapes. No drainage was necessary.

Intraoperative evaluation

The following parameters were recorded during surgery: the operative time (skin incision to skin closure), intraoperative exposition of the recurrent laryngeal nerve and parathyroid glands, blood loss (through dissection–suction spatula device), the number of clips used, the number of vessels coagulated with bipolar coagulation, and the number of ligatures used.

Postoperative follow-up

Neither the patients nor the nurses knew the relevant group assignment. Length of hospital stay was calculated as the time between hospital admission (in the morning of the surgery day) and discharge following the operation and expressed in days. An overnight hospital stay was mandatory for all the patients. For adequate evaluation of biochemical hypocalcemia, blood samples were analyzed on the morning after surgery and on the second postoperative day. Indirect laryngoscopy with a mirror was mandatory on the next day following the operation, being performed by an independent ear, nose, and throat (ENT) specialist to assess the recurrent laryngeal nerve morbidity. In cases of recurrent nerve palsy, an additional ENT examination was scheduled at 1, 3, and 6 months following surgery. On follow-up visits at 1 month following MIVAT, the scar length was measured and the patients' cosmetic satisfaction was assessed by the visual-analog scale with an additional scar cosmetic satisfaction reevaluation at 6 months postoperatively.

Cost-effectiveness analysis

For the cost-effectiveness analysis, we used an official in-hospital price-list for medical procedures of our hospital (4 euros per minute of operating theater use, 4 euros per minute of general anesthesia, 3 euros per single clip, 3 euros per single ligature, 100 euros per use of bipolar coagulation) and the cost of the HS device and the savings in the operating time.

Statistical analysis

The sample size was estimated based on the principle of detecting a 20% difference in the operating time with a 90% probability at $p<0.05$. The statistical significance of categorical variables was evaluated by the χ^2 test, whereas the unpaired Student's *t* test was used for the evaluation of continuous variables (STATISTICA, Stat-Soft, Katowice, Poland). All the data were entered onto a dedicated spreadsheet (Microsoft Excel 2002; Microsoft, San Jose, CA, USA) by a medical assistant and then analyzed by a statistician. A value of $p<0.05$ was considered to indicate significance.

Results

Among 2,008 consecutive patients referred for thyroid surgery throughout the study period, 109 (5.4%) were considered for unilateral thyroid lobectomy. Seventy-six individuals (69.7% of the patients with unilateral thyroid lesions and 3.8% of all patients) were found eligible for the MIVAT lobectomy. The remaining 33 (30.3%) patients were found not suitable for the unilateral MIVAT surgery due to a large diameter of nodules (18 cases) or discrete nodules found within the contralateral thyroid lobe on office ultrasound performed by an endocrine surgeon before final enrolment into the study (15 cases). None of the patients refused to participate in the study, which indicated their high motivation to undergo minimally invasive thyroid surgery in our tertiary referral center. A flow chart of the study is presented in Fig. 1.

The preoperative patient characteristics data were similar between both groups (Table 1). The major indication for the MIVAT lobectomy in both groups was follicular tumor followed by solitary toxic adenoma. None of these tumors were found to be malignant on final histopathology (probably due to a very low incidence of follicular cancer in regions without iodine deficiency and small diameters of the tumors eligible for MIVAT), and none of the patients required completion thyroidectomy.

The mean MIVAT operative time for lobectomy was significantly reduced in the HS-G vs CL-G group (31.4±

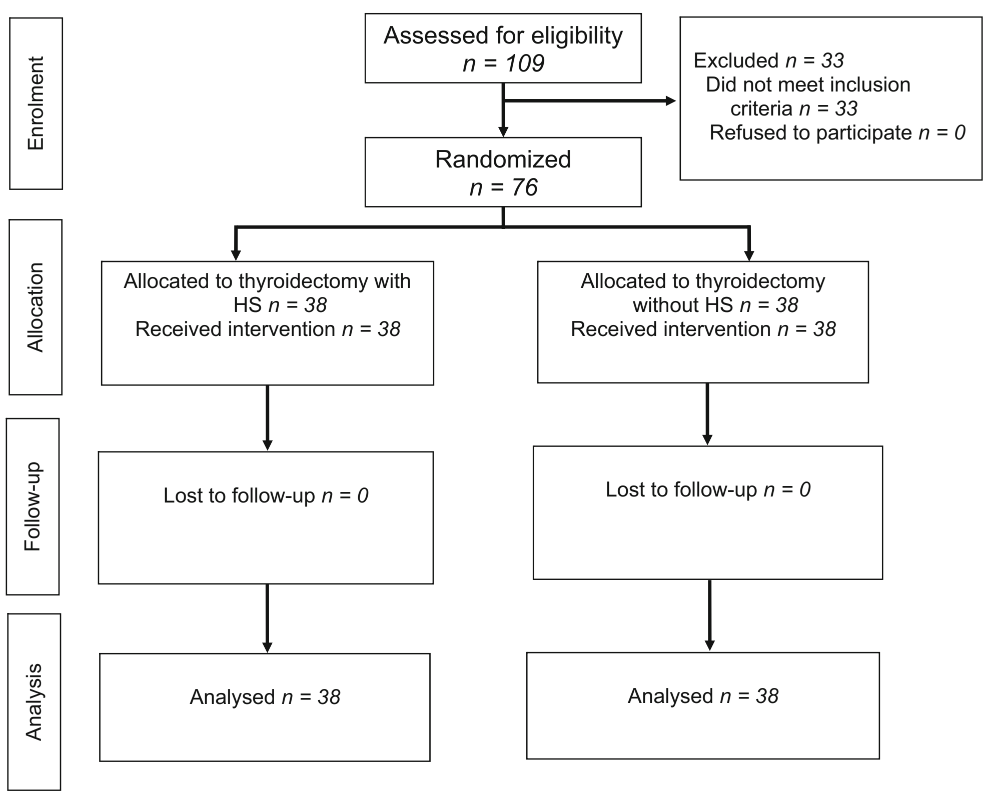

Fig. 1 Flow chart of the study. *HS*, ultrasonic harmonic scalpel

7.7 vs 47.5±13.2 min, respectively; $p<0.001$). This reduction was equal to 16.1 min, which is 33.9% shorter than the MIVAT lobectomy time without the use of HS. None of the HS-G patients required the use of clip or ligature to achieve hemostasis, whereas among CL-G patients, 7±4, 5±3, or 16±8 vessels were secured with clips, ligatures, or bipolar coagulation, respectively (the mean time spent on hemostasis and division of each of vessels was longer by 37 s in CL-G). The mean intra-operative blood loss was also significantly lower in HS-G (12.9±5.7 vs 32.8±13.0 ml, respectively; $p<0.001$). Small-wound seroma, which did not require wound revision, was found in zero vs one patient, transient hypocalcemia in two vs one patient, and transient recurrent laryngeal nerve paresis in zero vs one patient (HS-G vs CL-G, respectively; nonsignificant difference). The recurrent laryngeal nerve was identified and preserved intraoperatively in all the patients in both groups. No difference was found in the duration of postoperative hospitalization. The mean scar length was significantly shorter in HS-G (15.6±1.4 vs 21.5±1.9 mm, $p<0.001$). The cosmetic satisfaction was significantly higher in HS-G (88.9±9.7 vs 81.9±5.4 patients). However, in both groups, the cosmetic satisfaction increased with time, and at 6 months postoperatively this difference in cosmetic appearance became nonsignificant (Table 2).

The cost-effectiveness analysis showed that an additional 280 euros spent for a single-use ultrasonic shears was almost balanced by the 16.1-min gain in operative time and no need to use clips, ligatures, or bipolar coagulation; the combined cost of the latter elements was equal to 270.80 euros. However, if we include the depreciation costs of the ultrasonic HS impulse generator, the gap between these two values will increase to 20–30 euros per single operation.

Discussion

The thyroid gland has one of the richest blood supplies among the organs. Conventional thyroidectomy consists of devascularization of the thyroid by double ligating and dividing the branches of the thyroid vessels, followed by excision of the gland. Adequate hemostasis and keeping the operative field dry is of utmost importance during thyroid surgery due to anatomical complexity involved and the need to avoid damage to the superior and recurrent laryngeal nerves and parathyroid glands neighboring on the thyroid. Suture ligations are time-consuming, carry the risk of knot slipping, and are not suitable for endoscopic surgery. Also, vascular clips used initially in laparoscopic surgery instead of ligatures can occasionally be dislodged, leading to serious life-threatening hemorrhage in less than 1% of the operations [14]. Bipolar electrocautery is an attractive alternative to occlude small vessels but, due to the production of remarkable thermal spread to adjacent tissues and a high risk of thermal recurrent nerve or parathyroid glands injury, it is not safe to use it in close proximity to these vital anatomical structures.

The development of ultrasonically activated coagulating shears in the early 1990s has provided an alternative to other methods of controlling blood vessels. The device divides tissues by using high-frequency (55,500 Hz) ultrasonic energy transmitted between the instrument blades.

Table 2 Intraoperative and follow-up data

	HS-G	CL-G	p value
Operative time (min)	31.4±7.7	47.5±13.2	<0.001[a]
Blood loss (ml)	12.9±5.7	32.8±13.0	<0.01[a]
Clips/ligatures used (number)	0/0	7±4/5±3	<0.001[b]
Vessels secured with BC (number)*	0	16±8	<0.001[b]
Complications (number)			
Wound seroma	0	1	0.31[a]
Transient hypocalcemia	2	1	0.55[a]
Transient RLN paresis	0	1	0.31[a]
Postoperative stay (days)	1.3±0.5	1.4±0.6	0.51[b]
Scar length 1 month after surgery (mm)	15.6±1.4 (15–18)	21.5±1.9 (16–24)	<0.001[b]
Cosmetic satisfaction (VAS)			
1 month after surgery	88.9±9.7*	81.9±5.4**	<0.01[b]
6 months after surgery	96.7±3.2*	95.4±3.9**	0.11[b]

Values represent mean ± SD, unless otherwise indicated.
BC bipolar coagulation; *VAS* visual-analog scale (points)
*$p<0.01$ (t test); **$p<0.001$ (t test)
[a] χ^2 test
[b] t test

The active blade of the instrument vibrates longitudinally against an inactive blade over an excursion of 50 to 100 μm [15]. This mechanical action disrupts protein hydrogen bounds within the tissue. This takes place at a relatively low temperature (80°C), causing a lower degree of tissue injury (<2.0 mm) compared with both electrocautery and laser. Because the water in the tissue does not boil due to the mild increase in the temperature, the proteoglycans and collagen fibers in the tissue become denatured and mix with intracellular and interstitial fluids to form a glue-like substance (a coagulum) [16]. The coagulum seals the vessel lumen. An ultrasonic 5-mm HS CS-14C (Ethicon Endo-Surgery, Cincinnati, OH, USA) used in this study has been approved by the Food and Drug Administration for vessels up to 3 mm in diameter. The mean burst pressure for 3-mm vessels was estimated to be as high as 226 mmHg, whereas the mean length of thermal spread was equal to 1.6 mm [17].

Ultrasonic HS has been proven to be safe and effective in open and laparoscopic general surgery, allowing for the reduction of operative time in advanced operations. This significant reduction in the operating time is available by HS due to a combined dissection, coagulation, and division of tissues with the same instrument and no need to change tools. Open thyroid surgeons have also reported the safety and effectiveness of this instrument [9–13, 18–23]. In the majority of the reported series, the major benefits of HS used during open thyroidectomy were the reduction in the time of operation (between 15 and 35 min) and decreased blood loss. Voutilainen and Haglund suggested in their study an increased danger of the recurrent laryngeal nerve injury and a higher chance for hypoparathyroidism in operations performed with the use of HS by senior residents with limited experience in both thyroid surgery and HS dissection technique [24], but these data were not confirmed in other prospective randomized studies, in which operations were performed by experienced surgeons [10–13]. Meticulous, bloodless, and safe thyroid dissection facilitated by the use of HS can only be achieved by surgeons with experience in thyroid surgery and good understanding of the limits involved in the use of this adjunct. Before we commenced our randomized trial, we had used HS in 20 open thyroidectomies to become familiar with this equipment and performed 59 MIVAT operations using the clip-ligation technique for hemostasis, being already on the plateau of the learning curve [20]. When HS was used in this study, the operating time was reduced by 33.9% as compared to the MIVAT lobectomy with the use of clips and bipolar coagulation, the intraoperative bleeding was reduced by 60.8%, the scar length was reduced by 27.5%, and the cosmetic satisfaction was improved at 1 month following surgery by 7.9% (significant difference for all the values). These outcomes are comparable to the values reported by others [7, 25].

Moreover, some studies assessing the cost-effectiveness of HS in thyroid surgery pointed out a remarkable decrease in total hospitalization costs [10]. However, a recent report of Leonard and Timon did not confer any quantifiable benefit of HS in routine open thyroid lobectomy when compared with conventional techniques of hemostasis, as no reduction in operative time and increased expenses of the operation were noted in their experience [26]. Nevertheless, minimally invasive thyroid surgery has warmly embraced HS [7], which is employed by most surgeons performing either video-assisted or fully endoscopic thyroid surgery [6].

In this trial, only patients qualified for the unilateral MIVAT lobectomy were enrolled to make the statistical analysis and interpretation of the results more clear. It is important to stress that a recent meta-analysis published by Miccoli showed that, in up to 86% of the eligible cases, the MIVAT operation is offered to patients with benign thyroid nodules, in 38.7% constituting a MIVAT lobectomy, and in 61.2% constituting a total thyroidectomy [6, 25].

There were no significant differences between the study groups in the complication rates. We have not encountered any serious intraoperative or postoperative bleeding following the use of HS. The instrument we used was approved for vessels up to 3 mm, which is sufficient for the MIVAT lobectomy-eligible patients. However, for patients with Grave's disease, the second generation of that instrument (ACE) would probably be more appropriate, as it was approved for closing vessels up to 5 mm in diameter [25]. It should be stressed that we have not used HS very close to the recurrent laryngeal nerves or the parathyroid glands, and we performed blunt dissection with the HS shears to reach a minimum distance of 5 mm to these structures, which is regarded to be twice as large as the reported safe one [17]. One case of transient recurrent laryngeal nerve palsy was found in CL-G and may be explained by inadvertent stretching of the nerve during extraction of the lobe through the skin incision soon after the superior thyroid vessels had been divided. There was no impact of the use of HS on the incidence of transient hypocalcemia, which was suggested by others [9, 23]. We have not routinely used drainage of the wounds in both study groups and a small wound seroma was formed postoperatively in only one CL-G patient, which did not require surgical removal. Thus, despite the significant difference in intraoperative blood loss, an equal level of safe hemostasis was achieved in both groups before wound closure. We have not observed any significant difference in hospital stay between the study groups. The results of the cost-effectiveness analysis showed no economic benefit of the HS use in the MIVAT lobectomy, which was slightly (20–30 euros per operation) more expensive.

The outcomes of this study are limited by the power focused on the primary outcome being a decrease in the operating time and an insufficient number of patients enrolled to show slight changes in the incidence of morbidity. In spite of this, we can conclude that HS in the MIVAT operations is safe and facilitates dissection, allowing for a significant decrease in the operative time. The operation is potentially safer, as it is performed in a dry operative field, in which all the anatomical structures are easily visible with the video-assisted magnification. Despite their statistical significance, other benefits, such as a scar a few millimeters shorter or a slightly better early cosmetic result, are probably of minor clinical significance. However, we should consider if MIVAT operations performed with the CL technique with the slightly longer initial skin incision of 2 cm can offer similar early patients' cosmetic satisfaction to MIVAT operations with HS and initial skin incision of 1.5 cm. Nevertheless, in our practice, having finished this trial, we offer the MIVAT operation with HS to all eligible patients, as this tool is safe and makes the operation easier and faster, allowing for a higher volume of patients to be operated on each day with only a slight increase in the cost of operation. Thus, the answer to the question of whether the reduction in operating time and improved early cosmetic satisfaction are sufficient to compensate for the additional costs of the HS tool involvement during the MIVAT lobectomy will depend on local circumstances—the healthcare system and the acceptance of improved cosmetic outcomes as the leading benefits of the video-assisted dissection facilitated by ultrasonic HS.

Conclusion

HS in the MIVAT operations is safe and facilitates dissection, allowing for a significant decrease in the operative time. No reduction in the complication rate could be demonstrated in this study due to low power; however, HS reduced the intraoperative blood loss, allowing for operating in an almost bloodless field, which can potentially aid the MIVAT dissection and reduce the recurrent laryngeal nerves or parathyroid glands morbidity in a large series by an improved identification and preservation rate of these vital structures. Other benefits, such as improved early cosmetic results, can be offered with only a slight increase in the costs of operation, which is an attractive alternative for MIVAT without HS.

References

1. Hannan SA (2006) The magnificent seven: a history of modern thyroid surgery. Int J Surg 4:187–191 doi:10.1016/j.ijsu.2006.03.002
2. Becker AM, Gourin CG (2008) New technologies in thyroid surgery. Surg Oncol Clin N Am 17:233–248 doi:10.1016/j.soc.2007.10.001
3. Miccoli P, Berti P, Conte M, Bendinelli C, Marcocci C (1999) Minimally invasive surgery for thyroid small nodules: preliminary report. J Endocrinol Invest 22:849–851
4. Miccoli P, Berti P, Raffaelli M, Materazzi G, Baldacci S, Rossi G (2001) Comparison between minimally invasive video-assisted thyroidectomy and conventional thyroidectomy: a prospective randomized study. Surgery 130:1039–1043 doi:10.1067/msy.2001.118264
5. Miccoli P, Berti P, Frustaci G, Ambrosini CE, Materazzi G (2006) Video-assisted thyroidectomy: indications and results. Langenbecks Arch Surg 391:68–71 doi:10.1007/s00423-006-0027-7
6. Miccoli P, Minuto MN, Ugolini C, Pisano R, Fosso A, Berti P (2008) Minimally invasive video-assisted thyroidectomy for benign thyroid disease: an evidence-based review. World J Surg doi:10.1007/s00268-008-9479-y
7. Miccoli P, Berti P, Raffaelli M et al (2002) Impact of harmonic scalpel on operative time during video-assisted thyroidectomy. Surg Endosc 16:663–666 doi:10.1007/s00464-001-9117-3
8. Amaral JF (1994) The experimental development of an ultrasonically activated scalpel for laparoscopic use. Surg Laparosc Endosc 4:92–99
9. Defechereux T, Rinken F, Maweja S, Hamori E, Meurisse M (2003) Evaluation of the ultrasonic dissector in thyroid surgery. A prospective randomized study. Acta Chir Belg 103:274–277
10. Ortega J, Sala C, Flor B, Lledo S (2004) Efficacy and cost-effectiveness of the UltraCision harmonic scalpel in thyroid surgery: an analysis of 200 cases in a randomized trial. J Laparoendosc Surg Tech A 14:9–12 doi:10.1089/109264204322862289
11. Cordon C, Fajardo R, Ramirez J et al (2005) A randomized, prospective, parallel group study comparing the harmonic scalpel to electocautery in thyroidectomy. Surgery 137:337–341 doi:10.1016/j.surg.2004.09.011
12. Kilic M, Keskek M, Ertan T, Yoldas O, Bilgin A, Koc M (2007) A prospective randomized trial comparing the harmonic scalpel with conventional knot tying thyroidectomy. Adv Ther 24:632–638 doi:10.1007/BF02848788
13. Manouras A, Markogiannakis H, Koutras AS, Antonakis PT, Drimousis P, Lagoudianakis EE et al (2008) Thyroid surgery: comparison between the electrothermal bipolar vessel sealing system, harmonic scalpel, and classic suture ligation. Am J Surg 195:48–52 doi:10.1016/j.amjsurg.2007.01.037
14. Burkey SH, Van Heerden JA, Thompson GB, Grant CS, Schleck CD, Farley DR (2001) Reexploration for symptomatic hematomas after cervical exploration. Surgery 130:914–919 doi:10.1067/msy.2001.118384
15. Mc Carus SD (1996) Physiologic mechanism of the ultrasonically activated scalpel. J Am Assoc Gynecol Laparosc 3:601–608 doi:10.1016/S1074-3804(05)80174-4
16. Kanehira E, Omura K, Kinoshita T, Kawakami K, Watanabe Y (1999) How secure are the arteries occluded by a newly developed ultrasonically activated device? Surg Endosc 13:340–342 doi:10.1007/s004649900985
17. Harold KL, Pollinger H, Matthews BD, Kercher KW, Sing RF, Heniford BT (2003) Comparison of ultrasonic energy, bipolar thermal energy, and vascular clips for the hemostasis of small-, medium-, and large-sized arteries. Surg Endosc 17:1228–1230 doi:10.1007/s00464-002-8833-7
18. Siperstein AE, Berber E, Morkoyun E (2002) The use of the harmonic scalpel vs. conventional knot tying for vessel ligation in thyroid surgery. Surgery 137:137–142

19. Yildirim O, Umit T, Ebru M, Bulent U, Belma K, Betul B, Mee D, Omer C (2008) Ultrasonic harmonic scalpel in total thyroidectomies. Adv Ther doi:10.1007/s12325-008-0024-z
20. Konturek A, Barczynski M, Cichon S, Anielski R, Cichon W, Jamski J et al (2007) Ultrasonic scalpel versus classic procedures with limited access in thyroid gland surgery. Pol J Surg 79:848–859
21. Shemen L (2002) Thyroidectomy using the harmonic scalpel: analysis of 105 consecutive cases. Otolaryngol Head Neck Surg 127:284–288 doi:10.1067/mhn.2002.128072
22. Coimbra C, Defechereux T, Meurisse N, Squifflet JP, Meurisse M (2007) Ultrasonic scalpel in thyroid surgery. Rev Med Liege 62:83–85
23. Defechereux T, Meurisse M (2006) Hemostasis and ultrasonic shears for thyroid surgery. Ann Chir 131:154–156 doi:10.1016/j.anchir.2005.09.003
24. Voutilainen PE, Haglund CH (2000) Ultrasonically activated shears in thyroidectomies—a randomized trial. Ann Surg 231:322–328 doi:10.1097/00000658-200003000-00004
25. Berti P, Materazzi G, Galleri D, Donatini G, Minuto M, Miccoli P (2004) Video-assisted thyroidectomy for Graves' disease: report of a preliminary experience. Surg Endosc 18:1208–1210 doi:10.1007/s00464-003-9225-3
26. Leonard DS, Timon C (2008) Prospective trial of the ultrasonic dissector in thyroid surgery. Head Neck doi:10.1002/hed.20805