COMPARISON OF LATERAL THERMAL SPREAD USING MONOPOLAR AND BIPOLAR DIATHERMY, AND THE BIPOLAR VESSEL SEALING SYSTEM THERMOSTAPLER™ DURING THYROIDECTOMY*

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Electric devices enabling the maintenance of haemostasis during surgery have found application in modern thyroidectomy procedures. The haemostatic effect is associated with generation of heat, which apart from the intended result may bring about thermal tissue injury.

The aim of the study was to determine the thermal spread around the active tip of electric devices in the operating field during total thyroidectomy, and the safe temperature range during the operation of studied devices.

Materials and methods. Over 14 months from December 2009 until January 2011, 76 total thyroidectomy procedures were analysed. The surgeries employed mono- and bipolar diathermy as well as the ThermoStapler™ bipolar vessel sealing system. During the procedures, the thermal spread around the active tips of used electric devices was recorded with the use of high-definition camera. Comparable 5-second periods of electric device use at two power ranges (30 W and 50 W) were selected from the recorded material. The highest temperature of the active tip of electric devices was determined, and the 42°C isotherm was found with the use of computer image analysis, thus determining the safe distance of important anatomic structures from the active tip of the electric device.

Results. The temperature spread around the active tips of electric devices was recorded and the 42°C isotherm was determined. The diameter of this isotherm at the end of operation differed statistically significantly depending on the type of electric devices and power settings. The highest temperature, at both power ranges, was recorded for the bipolar vessel sealing system, while the lowest – for bipolar diathermy; at the same time a significantly lower 42°C isotherm diameter was found for ThermoStapler™ as compared with other devices. In all studied cases, the largest heat spread was found for monopolar diathermy.

Conclusions. The mean safe distance of the active tip of an electric device from important anatomic structures is 5 mm and depends on the device type and its power settings. Monopolar diathermy causes the strongest heating of surrounding tissues, and the ThermoStapler™ bipolar vessel sealing system, despite producing the highest temperature during operation, causes relatively small thermal injury to the surrounding tissues.

Key words: total thyroidectomy, electrocoagulation, thermography

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Reduction of surgical injury with the simultaneous retention of current safety and radical nature of surgical procedures forces the work in a relatively small operating field. In consequence, it becomes necessary to use modern devices enabling the maintenance of haemostasis in the small space of operating field (1, 2, 3).

Electric devices enabling the achievement of full and lasting haemostasis during total thyroidectomy supplant traditional surgical methods (ligature, haemostatic sutures) with no impact on the incidence of perioperative complications, while at the same time allowing to shorten the duration of the procedure (4-7). The mode of action of commonly used mono- and bipolar diathermy is based on raising the temperature of coagulated tissue due to the electric current between the active electrode and the neutral electrode (monopolar diathermy) or between the two arms of the bipolar device. Diathermy enables the safe sealing of vessels up to 3 mm in diameter. The small size of sealed vessels constitutes the limitation of this method. Research associated with the use of bipolar diathermy for the sealing of vessels of bigger diameter has led to the development of electrothermal bipolar vessel sealing systems. These devices use the combination of the thermal effect caused by the electric current of high frequency and modulated parameters and the mechanical pressure. Their mode of operation through, among others, structural changes in collagen and elastin, leads to lasting joining of sealed vessel walls and tissue structures. These systems enable a safe sealing of vessels of up to 7 mm in diameter (8, 9, 10).

All the modern techniques of vessel sealing are associated with generation of heat and its spherical spread, which causes thermal injury to the surrounding tissues (7, 11, 12).

In the publications analysed by the authors, concerning the thyroidectomy techniques, it is recommended to replace the electric devices with ligatures or clips near the laryngeal nerves, parathyroid glands and the trachea. In none of the publications available to the authors, the distance of safe use of electric devices has been specified, and the decision on the change of the method of haemostasis maintenance in the vicinity of crucial structures has been left to the surgeon (11, 13, 14, 15).

The aim of this study was the recording and analysis of temperature spread around various electric devices in the operating field during total thyroidectomy and the determination for them of the thermally safe use margin.

**MATERIAL AND METHODS**

Between December 2009 and January 2011 there were recorded with the use of thermovision camera the images from the operating field during 76 elective procedures of total thyroidectomy. The surgeries were performed by the same surgical team. The exclusion criteria were large goitre volume (>100 ml) and intensified vascular flow observed during pre-operative Doppler ultrasound examination.

The study employed the A40MF thermographic camera by FLIR SYSTEMS, with temperature resolution of 80 mK, enabling the recording of 16-bit images of 60 Hz frequency, operating within the wavelengths of 7.5-13 µm. The thermographic camera was placed above the operating field, perpendicularly to it, at a distance of 80 cm.

From the recorded material, for further analysis, for each device, there were selected 10 independent 5-second (±0.6 s) periods of operation, covering the cycle from the moment of start of operation of unheated electric device until the achievement of haemostasis, within one of the used power ranges: 30 W and 50 W.

In the analysis of obtained thermovision images, there was used the ThermaCAM Researcher HS™ software by FLIR SYSTEMS, enabling the temperature determination for a single pixel (fig. 1).

During the surgical procedures, there was used monopolar diathermy (straight lancet R-2003 Emed Polska), bipolar diathermy (straight forceps C-605-039 Emed Polska) and ThermoStapler™ bipolar vessel sealing system (angled clamps 80-971-16 Emed Polska) with the use of ES-Vision apparatus (Emed Polska). The used power parameters were selected remotely by the surgeon (switch MultiSwitch 100-203 Emed Polska), as required perioperatively. The temperature of the active part of each electric device at the end of 5-second operation cycle was determined.

The determination of the extent of thermal injury consisted in the determination of the diameter of 42°C isotherm around the used device, followed by the measurement of the distance between this isotherm and the edge of the active part of the electric device (fig. 2).
Monopolar, bipolar diathermy, and bipolar vessel sealing system in thyroidectomy

In the statistical analysis of obtained results, the Student’s t-test was used, with the $p \leq 0.05$ being adopted as statistically significant.

RESULTS

The temperatures determined at the tips of electric devices at the end of operation differed statistically significantly depending on the type of the device. The highest temperature, both for 30 W and 50 W, was observed for the ThermoStapler™ bipolar vessel sealing system ($82.3°C$ and $100.07°C$, respectively), lower for monopolar diathermy ($78.12°C$ and $82.14°C$, respectively), and the lowest temperature was observed for the active tips of bipolar forceps ($63.8°C$ and $70.27°C$, respectively).

The distances from the electric device tip edge to the $42°C$ temperature border of tissue ($42°C$ isotherm) differed in the lower power range: for ThermoStapler this distance was significantly lower as compared with monopolar and bipolar diathermy, between which no significant differences were observed.

At higher power settings the observed differences were not statistically significant.

All the studied devices delivered statistically significantly lower temperature and smaller distance from the $42°C$ isotherm during their operation within the range of 30 W as compared with the range of 50 W.

The largest observed distances from $42°C$ isotherm to the active tip of monopolar diathermy, bipolar diathermy and ThermoStapler were 3.9 mm, 3.85 mm and 3.79 mm, respectively, for 30 W power, and 5.8 mm, 5.2 mm and 4.9 mm, respectively, for 50 W (fig. 3, 4, 5, 6).

DISCUSSION

The benefits stemming from the use of electric devices in thyroidectomy are associated with a significant shortening of procedure duration, reduction in blood loss, reduction in postoperative pain and reduction in inflammatory reaction and incline to their wide use (4, 5, 6, 15).

As compared with traditional methods, such as vascular ligation, the new techniques of haemostasis maintenance are associated with generation of large amount of heat which may lead to injury to anatomically important structures, such as the parathyroid glands, recurrent laryngeal nerve and external laryngeal nerve (3, 12). Despite the wide use in modern

Fig. 1. Representative operating field images: a) real image, b) thermovision camera image, c) image post digital processing enabling the isotherm determination

Fig. 2. Schematic diagram of determining the distance from the active tip of the device to the $42°C$ isotherm

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Średnica izoterm $42°C$
$42°C$ isotherm diameter

Aktywna końcówka narzędzia
Active tip of the device

Izoterm $42°C$
$42°C$ isotherm

Odkł. od aktywnej końcówki
Distance from the active tip to the $42°C$ isotherm

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surgery of electric devices for haemostasis maintenance in the operating field, there is no information on the extent of thermal injury to the surrounding tissues. The presented study is, according to the authors’ knowledge, the first attempt at perioperative determination of the safety margin of this type of devices during total thyroidectomy in patients qualified for this type of procedure. The available studies have focused mainly on histological changes and their extent in tissues exposed to high temperatures (1, 16, 18). One of the reports concerning the lateral spread of heat during the use of electric devices is the experimental study by Sutton and colleagues. The study determined the temperature of active parts of various electric devices, the time until the return to the safe temperature of the device after its use, and the temperature at the distance of 1 cm from the site of device application (11). The temperatures obtained by English researchers during the work with comparable devices were clearly lower than temperatures observed in the present study. The reason for such discrepancies, with comparable dependency on power and device type, could be the fact that the study was conducted on fragments of dead tissue maintained at 20°C, which could significantly influence the obtained results, precluding their use in everyday clinical practice.

The study by Smith and colleagues has compared, with the use of thermovision camera, the temperature spread during thyroid gland parenchyma resection in an animal model, with the use of, among others, LigaSure bipolar vessel sealing system (15). It was found that the maximum temperature of the active tip was 96.52°C, and the 40°C isotherm was of 4.1 mm in diameter; the results are similar to those obtained for ThermoStapler in the present study (100.07°C and 4.7 mm), and the discrepancies may stem from the difficult to be compared power settings of both devices (generators).

The factors responsible for the thermal destruction of tissues are temperature, duration of acting on the tissue and thermal conduction of the tissue. No data were found in the available publications unambiguously determining what temperature and time of its action are safe for specific tissues. The adoption by us of temperature below 42°C as the safety threshold stems from the fact that an increase in tissue temperature above this temperature causes both the damage to thermolabile cell
membranes (by increasing their permeability and rigidity) and the protein denaturation (19), and hence it results in irreversible changes that could be the cause of postoperative complications. It should be emphasised that the duration of coagulation is of crucial importance particularly in the area of important anatomic structures, since prolonged coagulation time significantly raises the temperature of the active tip of an electric device and could be the cause of thermal injury leading to postoperative complications in the form of hypoparathyroidism and recurrent laryngeal nerve paralysis.

The limitation of the present work is the study of low power parameters of the electric devices only, and the relatively short cycle of their operation, stemming from observations and analysis of routinely performed surgical procedures, during which the power setting and duration of action were decided by the surgeon and not the research team. Based on the results obtained by us, it could be expected that a further increase in power might lead to an increase in the distance of 42°C isotherm from the device, and thus to an increase in the safety margin, but the verification of this thesis requires further studies.

CONCLUSIONS

The knowledge on the mechanisms of development and extent of thermal injury caused by modern electric devices could prove helpful in the correct selection and proper use of techniques providing perioperative haemostasis.

The safe distance of the active tip of an electric device is dependent on its type and power parameters. In all the studied devices, lower power parameters were associated with a lower temperature of device operation and a shorter distance to the threshold isotherm. Monopolar diathermy causes the strongest and the ThermoStapler bipolar vessel sealing system the weakest heating of surrounding tissues. The safe distance from the active part of the device could be accepted as 4 mm for 30 W power and 5 mm for 50 W. Thus, it is recommended to use as low power settings of devices as possible during work in the vicinity of important anatomic structures.

The possibility of effective sealing of vessels of bigger diameter, with comparable thermal injury, justifies the replacement of mono- and bipolar diathermy with the ThermoStapler vessel sealing system during thyroid gland surgery.

REFERENCES


