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Real Time Monitoring of Temperature Changes in Neurovascular Bundles During Robotic Radical Prostatectomy: Thermal Map for Nerve-Sparing Radical Prostatectomy

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Abstract

Objective: A rise in temperature of more than 55°C in tissues, even for short a duration has been implicated in irreversible tissue damage. This study was aimed at recording real time temperature changes at the neurovascular bundle (NVB) during the use of cautery in robotic radical prostatectomy.

Methods: The temperature was monitored with a needle electrode in 15 cases of athermal nerve sparing and 10 cases of non-nerve sparing robotic radical prostatectomy (RRP). The needle was placed in the peritoneal cavity through the camera port and inserted around the NVB. Body temperature was recorded by nasal cannula and compared with the baseline temperature at the neurovascular bundle. The distance of the needle probe from the area of cautery use, changes in temperature at the neurovascular bundle and the duration of cautery use was recorded during the use of monopolar and bipolar current in tissue dissections.

Results: The mean baseline temperature at the neurovascular bundle was 0.8^0C lower than the body temperature. Average duration for cautery use at the anterior bladder neck and NVB with monopolar and bipolar current was 53.6 (45–65) and 79.8 (70–92) and 56.8 (45–60) and 65.7 seconds (59–76) respectively. The mean temperature rise during bladder neck dissection (distance more than 1 cm) was 43.6°C [36.4–47.3°C] with the monopolar and 38.8°C [36.8°–42.6°C] with bipolar. During NVB dissection, the mean temperature rise was 53.6°C (45.1 to 68.1°C) with monopolar and 60.91°C (47.2 to 109.8°C) with bipolar. Though this difference was not significant, the mean time to return to baseline temperature was 3 seconds more with bipolar than monopolar.

Conclusions: Bipolar cautery may not be safer than monopolar because of a greater rise in temperature of surrounding tissues within 1 cm of its use. Further investigation is needed to fully establish the pathologic consequences associated with increased temperature due to cautery.

Introduction

There has been a recent surge in the use of robotic technology in the treatment of clinically localized prostate cancer. The main reasons for early embracement of this modality are reduced blood loss, magnified 3D vision and dexterity of surgical instruments which allow precise dissection in small space. While robotic technology offers features that are advantageous during nerve sparing robotic prostatectomy, deviation from principles and techniques used during conventional radical prostatectomy has triggered criticism. One of the most significant deviations from traditional surgery is the liberal use of electro-cautery during most of the robotic surgery. While traditional surgeons advocate minimal use of current and heat in the proximity of neurovascular tissue to prevent nerve damage, the extensive use of elec-

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trocautery in robotic surgery is a cause of considerable debate amongst urologic-oncologists.

Some robotic surgeons have responded to this concern by modifying their technique. Modifications to reduce adverse effects of electrocautery include release of neurovascular bundles without the use of electrocautery, the exclusive use bipolar cautery in dissection and sharp dissection in conjunction with bulldog clamps on the pedicles.[1] Still others propose that electrocautery should be avoided during the release of neurovascular bundles and during dissection of seminal vesicles due to their proximity to the proximal neurovascular plate (PNP) which forms the nerves preceding the neurovascular bundle (NVB).[2,3]

Electrocautery coagulates and cuts tissue with high temperature generated by an electrical current. High temperature exposures ($>50°C$) result in immediate, irreversible conformational changes and denaturation of tissue and cellular proteins, leading to thermal coagulation of the tissue.[4] Although the majority of heat is concentrated at the location of the instrument, electrocautory use during surgical dissection has been associated with increased temperature in the surrounding tissue. If exposed to sufficient heat, thermal injury to the surrounding tissue and nerves may lead to irreversible damage.[5]

To our knowledge, there are no previous works that document real time temperature changes of the surrounding tissue during the use of monopolar or bipolar cautery. In this paper, we report our examination of the temperature changes in surrounding tissue during monopolar and bipolar cautory use during robotic assisted radical prostatectomy in relation to electrosurgical generator settings, duration of cautery usage, and distance of cautery from the nerves.

Methods

From August 2006 to November 2006, the temperature was recorded around the neurovascular bundle at the base of the prostate in 15 cases of athermal and 10 cases of non-nerve sparing RRP at New York Presbyterian hospital, Weill Cornell Medical college, NY. All patients had localized carcinoma of the prostate. Non-nerve sparing radical prostatectomy was conducted in men with clinical diagnosis of T3 cancer in 6 patients and impotency with high volume disease in 4 patients.

In an athermal RRP, cautery is used in dropping the bladder, cutting the bladder neck to reach to Foley catheter and dissecting posterior bladder neck in its central part to reach to the vas deferens. Sharp dissection and clips are used without cautery in subsequent steps including incision of the endopelvic fascia, seminal vesicle dissection, control of prostatic pedicle, NVB dissection, and apical dissection.

To investigate the effects of monopolar and bipolar cautery in surrounding tissues during the athermal technique, the bladder neck was incised using monopolar cautery on one side and bipolar cautery on the other. During dissection of each side, the temperature around the ipsilateral NVB was continuously measured at the base of the prostate. Temperature changes at baseline, during cautery use and following cautery were documented. (Fig. 1) The distance of the temperature probe from the use of cautery site was measured by a sterile plastic ruler.

In the 10 patients undergoing non nerve sparing surgery, monopolar cautery was used during dissection of the nerovascular bundle on one side and bipolar cautery was used during dissection of the contralateral neurovascular bundle. Temperature was monitored in the same way as in the athermal group.

Temperature Monitoring Unit

Temperature monitoring was done using a needle electrode historically used to measure myocardial temperature during cardioplegia in open-heart surgery. The electrode is capable of recording temperature changes as small as 0.1°C (Genesee Biomedical, Inc., Denver, CO, USA) (Fig. 2). For this study, the needle electrode entered the peritoneal cavity through the camera port and was placed at a depth of 1 to 1.5 cm at the NVB at the base of the prostate Before the

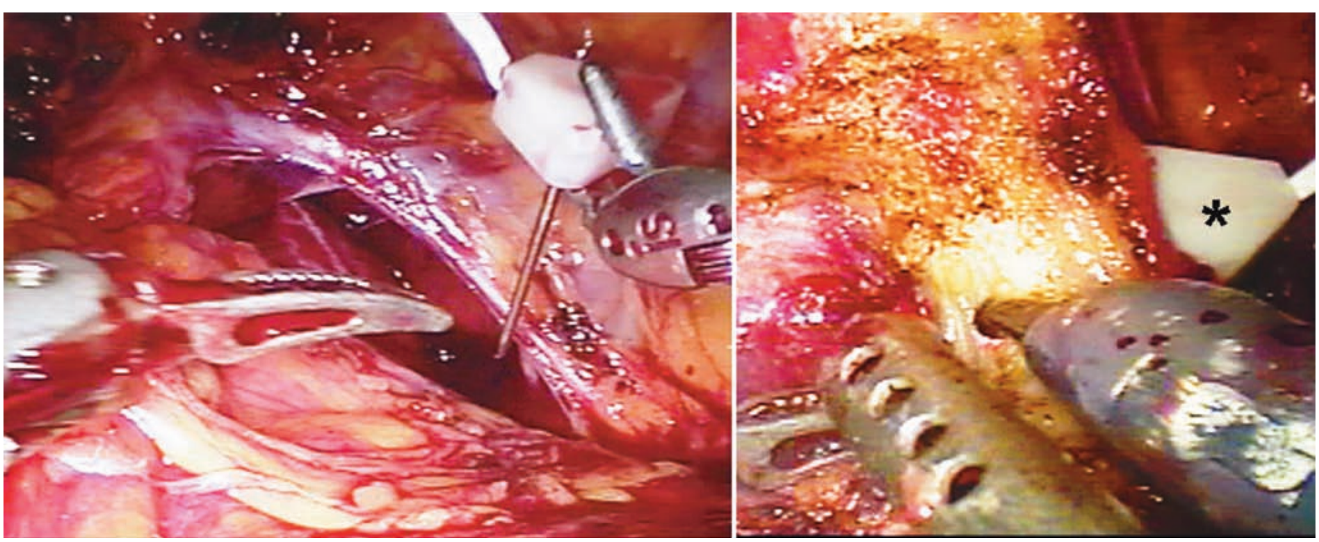

FIG. 1. Temperature probe to record the temperature rise while cutting the bladder neck using monopolar cautery. *Temperature probe.

FIG. 2. Temperature probe.

operation, the thermal device was calibrated outside the patient using skin thermometer and infrared temperature monitoring unit.

Electrosurgical Unit

The electrosurgical generator output power used for monopolar and bipolar cautery was 50 Watts in all the patients. (Valleylab, Boulder, CO, USA).

Outcome Measurements

Body temperature was recorded by nasal cannula and compared with the baseline temperature at the NVB. The duration of the cautery use, distance of the needle probe from the area of cautery use, the rise of temperature in centigrade during cautery use and the time to baseline temperature was recorded during both monopolar and bipolar current use.

Data Collection and Statistical Analysis

Microsoft Excel® was used to record and store data and to conduct statistical analysis of the data with the student t test.

Results

As this was a real-time study, cautery duration varied in different patients according to the size of the prostate and anatomy around the bladder neck. Average duration of cautery use at the anterior bladder neck with monopolar and bipolar current was 53.6 (45–65) and 79.8 (70–92) seconds respectively. During the neurovascular dissection in the non-nerve sparing procedure, the mean duration of cautery use was 56.8 (45–60) seconds with monopolar and 65.7 (59–76) seconds with bipolar.

The mean baseline temperature at the NVB for patients undergoing athermal technique was 34.8°C; 0.8°C lower than the body temperature. The mean temperature rise at the NVB during anterior bladder neck dissection (distance more than 1 cm) was 43.6°C [36.4–47.3°C] with monopolar dissection and 38.8°C [36.8°–42.6°C] with bipolar dissection. ($p <$ 0.0001) (Table 1) Although the rise in temperature was greater with monopolar current, the maximum temperature was not sufficient to cause irreversible damage. (e.g., 55°C)

During the neurovascular bundle dissection in the non nerve sparing surgery using cautery, the baseline temp was 34.83°C; 1.1°C lower than the body temperature. The mean temperature rise during monopolar cautery use was 53.6°C (45.1 to 68.1°C) and 60.91°C (47.2 to 109.8°C) with bipolar (Table 1). Following cautery use, the temperature reached the nadir after a mean time of 3.4 seconds (3–5 seconds) after monopolar use and 6.4 (5–9) seconds after bipolar use.

Although the difference in average temperature elevation during monopolar and bipolar cautery use was not significantly different in the non-nerve sparing group, the time to reach the nadir during bipolar cautery was three seconds more than during monopolar use (Fig. 3).

Although tissues <1 cm from the site of cautery use have a 7.3°C greater increase in average temperature with bipolar cautery use than monopolar use, the average temperature increase is not statistically significant. Additionally the mean time to return to baseline temperature was three seconds more with bipolar than monopolar. In tissues >1 cm, the average increase in temperature was significantly greater with monopolar use than bipolar use, however the increase in tissue temperature was not adequate to cause long term tissue damage temperature rise below 55 °C during mono or bipolar cautery use.

Discussion

Radical prostatectomy is the mainstay of the surgical approach to localized carcinoma of the prostate and robotic radical prostatectomy (RRP) has become a popular surgical approach. Though the urinary continence after robotic radical prostatectomy has been reported to be comparable to results found in conventional nerve sparing radical prostatectomy series, potency outcomes continue to be a challenge following both surgical approaches.[6,7]

Inconsistency in the recovery of sexual function after radical prostatectomy is an intriguing aspect of robotic radical prostatectomy. Despite uniformity in the nerve-sparing procedure, in an expert's hand, with similar confounding factors (such as disease stage, grade, age, and body mass index), sexual function recovery is not homogeneous. There is increasing evidence in human and animal models that minimizing the use of thermal energy during nerve-sparing radical robotic prostatectomy leads to better sexual function recovery.[1,8] Var-

TABLE 1. TISSUE TEMPERATURE CHANGES BY LOCATION AND CAUTERY CURRENT TYPE

	Monopolar	*Bipolar*	P *value*
At anterior bladder neck (>1 cm)	43.6°C [36.4–7.3°C]	38.8°C [36.8°–42.2°C]	<0.0001
At NVB (<1 cm)	53.6°C [45.1–68.1°C]	60.91°C [47.2°–109.8°C]	0.3

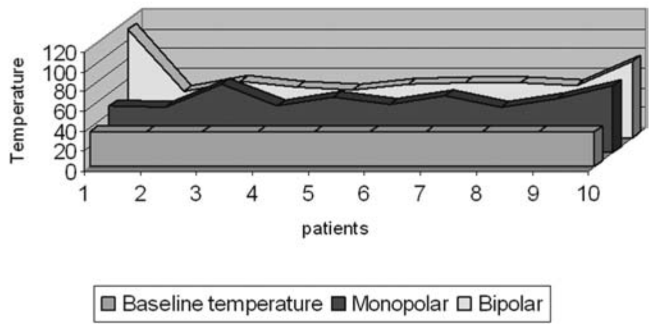

FIG. 3. Temperature rise with monopolar and bipolar at the distance of less than 1 cm.

ious procedural modifications such as the use of clips, bipolar cautery and the use of suture have been described to minimize the damage to the primary neurovascular bundle (NVB).[1]

The neurovascular bundle anatomy has been well described by Walsh as a plexus of autonomic nerves situated lateral to the vascular tree in very close proximity to the prostatic capsule (1.5 to 3 mm).[9] The nerve tissue preceding the NVB, called the proximal neuronal plate (PNP), includes vesicle and prostatic subdivisions of the pelvic plexus.[2,3] The PNP is prone to injury by lateral dissection of the seminal vesicles and dissection of the pedicle. Therefore, considering our study findings, it is imperative to consider the safe distance needed to protect tissues when using cautery to safeguard the neurovascular tissue responsible for erection.

Although the pedicle and seminal vesicle dissections are done using clips during the athermal RRP, cautery is used in this technique for dissecting the anterior and posterior bladder neck to reach the vasa deferentia and seminal vesicles. The present study analyzed the real-time documentation of temperature rise at the NVB during the use of monopolar and bipolar cautery at the bladder neck and during the dissection of the neurovascular bundle.

We found that within a 1 cm of cautery use the average increase in temperature and the average time needed for tissue to reach nadir level after cautery use was higher with bipolar current than in monopolar current in non-nerve sparing cohort. Considering this difference, it is possible that longer duration of elevated temperature can lead to additional thermal damage to the surrounding tissue. In a study evaluating the impact of continuous irrigation with cold water or saline during electrocautery use, lowering tissue temperature with irrigation was proven to be beneficial in reducing the collateral damage of the heat.[9] Furthermore, the study demonstrated that a temperature rise using bipolar cautery was observed, irrespective of irrigation use, but irrigation resulted in a more rapid reversal of the temperature rise.[10]

Slight temperature elevations (41–45°C) of relatively short duration may damage cells but are generally repairable and considered non-lethal.[4,5] In this range, heat-mediated physiologic effects include acceleration of metabolism or cellular activity, inactivation of enzymes, rupture of cell membranes, and the delayed onset of increasing blood flow and vessel permeability.[4,5] Coagulation generally occurs at 45-55°C where protein and other macromolecular denaturation begins and forms a homogeneous mass of tissue. These changes are irreversible.[4,5]

In contrast to the minor temperature elevation and reparable tissue damage resulting from monopolar current use in tissue $>$1 cm from cautery use, we found temperature increases of up to 109.8°C with bipolar current in tissues $<$1 cm from cautery use. Bipolar cautery is often used under the assumption that it is safer than the monopolar current to control the pedicle during the NVB dissection. However, our findings suggest that bipolar cautery results in a greater increase in temperature in surrounding tissues that persist for a longer duration than changes due to monopolar current.

The greater rise in temperature during bipolar current can be explained by the interaction of electric current with the biological tissue. Monopolar current passes from the active electrode to the grounding pad, often through a large area, stimulating muscle and nerve fibers. With bipolar current, both the active and dispersive electrodes are very close to each other, generating a high current density and a large heating effect.[11] In monopolar cautery, current density is extremely high at the point of tissue contact, causing a cutting action by abrupt tissue heating. The current flow is then dispersed within the first few cell layers, beyond which current density decreases significantly with an inconsequential heating effect. With bipolar, the heat dissipated through the small amount of tissue between the electrodes is very high.[11,12]

The magnitude of temperature increase during electrocautery use may be directly related to poor clinical outcomes following liberal use of thermal energy during surgery. The cavernosal autonomic nerve complex is an unmyelinated nerve structure which may be particularly susceptible to thermal damage. Although the effect of heat on the myelinated nerves has been described in many animal studies there is little data on the effect of heat on unmyelinated cavernosal nerves.[10,13,14] In a study by Ong AM et al[8] of open radical prostatectomy in the canine animal model, monopolar, bipolar and harmonic energy sources were used to separate the neurovascular bundle from the prostate. Intra-cavernosal pressure measured immediately and at 2-weeks post op showed significant decrease in intracorporeal pressure with nerve stimulation following the use of all three types of energy. In this study, thermal energy was used for one second and the impact of thermal damage was measured by changes in intra cavernosal pressure. Although this paper lends credence to the idea that electrocautery can damage cavernous nerves, in contrast to this study, energy used in surgery is continuous and real time measures of thermal damage make our investigation more applicable to clinical practice.

There is mounting evidence in support of avoiding electrocautery at the neurovascular bundle in robotic radical prostatectomy. Because cautery is frequently used in the bladder neck and seminal vesical dissections that are key to adequate exposure of the neurovascular bundle for nerve sparing surgery, an improved understanding of the temperature changes in surrounding tissue that result from mono and bipolar currents may encourage cautious use of cautery when in close proximity to neurovascular tissues.

Limitations of this study include imprecise placement of the needle at the neurovascular bundle and low subject number. Despite these limitations, our investigation provides a basis for a conceptual understanding of how electrocautery, even used $>$1 cm away from the NVB can result in nerve damage.

Conclusions

Our investigation provides real time measurement of temperature changes in tissue <1 cm and >1 cm away from monopolar and bipolar electrocautery use. Our findings suggest that in tissue <1 cm from electrocautery use, bipolar current results in a greater increase of temperature that persists for a longer duration than temperature changes due to monopolar current at the same distance. In tissues >1 cm from cautery use, our data suggests that monopolar current causes a significantly higher temperature change compared with bipolar current but temperature elevation however are not sufficient to cause irreparable tissue damage with either current. Overall, our findings suggest that bipolar current should be used with great caution or avoided when in close proximity to neurovascular tissues because it may inadvertently induce thermal damage to tissue within 1 cm due to persistently increased temperature. The results of this study provide evidence against the common belief that bipolar cautery is safer than monopolar cautery; however, further studies are needed before a definitive conclusion of the saftey of mono versus bipolar current may be made.

Disclosure Statement

No competing interests exist.

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Abbreviations Used

NVB = neurovascular bundle
RRP = robotic radical prostatectomy