

Experimental study of transurethral robotic laser resection of the prostate using the LaserTrode lightguide

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Abstract. A longer operating time and steeper learning curve in mastering the techniques for transurethral laser resection of the prostate are the main problems faced by surgeons in addition to the existing ones in standard transurethral resection of the prostate (TURP). However, these disadvantages can be alleviated with the introduction of a treatment procedure designed and developed based on an integrated system of computer, robotics and laser technology. *In vitro* experiments were carried out to determine variables affecting the vaporization and coagulation lesions, in order to study the effectiveness and feasibility of robotics for this procedure. Human cadaveric prostates and fresh taut chicken breast tissues were irradiated with different parameters using the LaserTrode lightguide in contact with the tissue. The effects of irrigant flow rate, fiber/tissue angle of inclination, number of passes, direction, speed and power of laser on the volume of tissue vaporized and coagulated, were assessed. The final phase of the experiments includes executing the robotic motion plan for the laser resection procedure on the human cadaveric prostate tissue embedded in an anatomically alike prostate phantom. It was concluded from our study that power and speed of laser are the most significant parameters influencing the volume of the vaporized and coagulated lesion. Comparison of removal rate using the new treatment procedure of robotic laser resection of the prostate with TURP and HoLRP evinced equivalent results. © 2001 Society of Photo-Optical Instrumentation Engineers.
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1 Introduction

Benign prostatic hyperplasia (BPH) is a common problem among older men with voiding difficulties that impact quality of life and the perception of well being.¹ Evidences for minimally invasive surgical (MIS) treatment of BPH are patients with urinary retention (complete inability to urinate requiring catheterization), renal insufficiency, urinary tract infections, recurrent gross haematuria, bladder stones and large bladder diverticula.^{2–4} The gold standard for MIS treatment is the transurethral resection of the prostate (TURP).⁵ Because of the disadvantages associated with the TURP procedure that resulted in morbidity in 18%, blood loss with the requirement of transfusion occurring in 2.9%–19.6% and transurethral resection (TUR) syndrome occurring in 0.2%–2.0% of the cases,^{2,6–9} an aggressive search for alternative medical and less morbid surgical therapies for BPH are still continuing.

Laser prostatectomy¹⁰ has been shown in numerous studies to provide an excellent, safe and effective alternative to TURP for the treatment of moderate to severe dysfunction and urinary retention due to BPH.^{11–13} The morbidity associated with laser prostatectomy has been shown to be drastically less than that associated with TURP, including negligible incidences of

bleeding and need for transfusion, intraoperative fluid absorption, and postoperative incontinence.^{14,15} Of all the different types of laser prostatectomy techniques, the holmium laser resection of the prostate (HoLRP) technique mimics closest to conventional TURP with the immediacy of intraoperative tissue removal and early postoperative voiding improvement classically associated with TURP, yet combining the advantages of minimal perioperative morbidity.^{16–19}

At present, HoLRP is as efficient as TURP in removing BPH tissue for prostate glands smaller than 80 ml (estimated by transurethral ultrasound) and is subjected to the level of experience of the surgeon. In large prostates (>80–100 ml) this advanced technique, however, proves to be less efficient. This is primarily due to the time needed to incise the prostate lobes that have been partially enucleated, into smaller manageable fragments. These fragments must be of a size that can be safely retrieved via the urethra and preferably irrigated from the bladder through the resectoscope sheath. It is difficult to gauge the size of the fragments resected during an operation.^{20–24} In addition, surgeons could become uncomfortable when forced to work in confined spaces over a long period of time; they may have small hand tremors and get tired, resulting in proneness to errors. The other disadvantage

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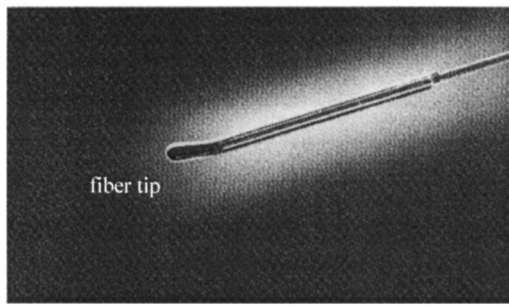


Fig. 1 LaserTrode lightguide (Dornier Medtech).

of the HoLRP technique is the longer learning curve associated with this technique, due primarily to its more technically demanding nature which requires significant endoscopic skill to manipulate the laser fiber.^{18,25} Other inherent problems encountered while using the holmium laser include continuous shortening of the fiber end during laser resection which requires frequent stripping of the fiber cladding to expose new fiber and vigorous vibrations of the fiber tip, resulting in difficulty at controlling the incisions.^{26,27}

The laser system is a part of an integrated system of robotics and computer technology which possesses complementary capabilities like consistency in the speed and tissue vaporization of the robotic laser resection procedure, controllability in predetermining the size of prostatic fragments to be resected and repeatability of the procedure that would provide a shorter operating time. These capabilities can remedy the problems faced by the surgeon in conventional laser resection. The primary aim of this experimental study served to investigate the effectiveness and feasibility of robotic laser resection of the prostate by determining the variables affecting the vaporization and coagulation lesions after irradiating with the Nd:yttrium–aluminum–garnet (YAG) laser.

2 Materials and Methods

2.1 Laser and Application System

The laser system used was a Nd:YAG continuous wave laser system (Dornier Medilas Fibertom 5100, Dornier Medtech, Germany) with a wavelength of 1064 nm operating between 60 W and the maximum operating power of 100 W. LaserTrode lightguide (Dornier Medtech, Germany) of 600 μm core diameter and 2.3 mm maximum diameter of the fiber tip was used to deliver a continuous laser beam (Figure 1).

2.2 Tissue Sources

For the *in vitro* experimental studies, 76 samples of freshly harvested chicken breast tissues and five samples of human cadaveric prostates were irradiated with the Nd:YAG laser. The chicken breast tissues measuring 40 mm \times 20 mm \times 20 mm were taut under running irrigant of 0.9% saline solution and 228 lesions were made by varying the irrigant flow rate (0.23 L/min, 1.10 L/min), fiber/tissue angle of inclination ($0^\circ, 10^\circ$), number of passes (one pass, two passes), direction (forward, backward, clockwise, counterclockwise), speed (1–3 mm/s) and power of laser (60–100 W).^{10,28,29} Taut chicken breast was used for these experiments because of their little glandular content, visible coagulation/

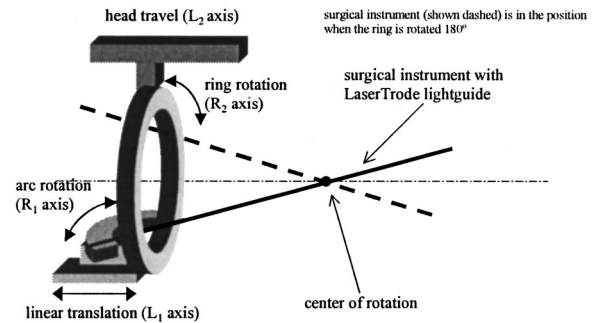


Fig. 2 Schematic diagram of the motion device showing both the linear and angular axes of motion.

denaturation zone (denoted by tissue blanching) and the large number of lesions needed for comparing different parameters. Additionally, prior studies on tissue effects have been published using chicken breast and comparisons would be more relevant.^{10,30} It was found that the tissue hardness of taut chicken breast bears the closest resemblance to the tissue hardness of a human cadaveric prostate and contains less variability in the tissue hardness,³¹ thus having a more predictable behavior that would aid in the accurate conclusion of the experimental results. Eighteen lesions on the human cadaveric prostate were made by varying the speed (1–3 mm/s) and power of laser (60–100 W).

2.3 Experimental Setup

To determine the variables affecting the vaporization and coagulation lesions, each tissue was fixed on a holder and irradiated by the Dornier LaserTrode fiber using a linear and angular motion device that provides an adjustable controlled speed of laser (Figure 2). The arc angle of the R_1 axis in Figure 2 was used to maintain constant angle of inclination between the fiber and the tissue surface in both the longitudinal (forward, backward direction) and transverse (clockwise, counterclockwise direction) motion. Tissue was vaporized in either one or two irradiation passes of the laser fiber in the direction of L_1 axis to a fixed depth of 2 mm using a 26F (Karl Storz) resectoscope equipped with a 7F laser bridge and a continuous flow system. For all conditions, the laser was used in standard contact vaporization mode.

To study the effectiveness and feasibility of robotic laser resection of the prostate, a prostate phantom (Limbs & Things, U.K.) was used to provide an anatomically alike (with verumontanum, urethra, bladder and lobes) replica of the human prostate with the human cadaveric prostate attached (by pins) as the median lobe. The linear and angular motion device executing the robotic motion plan for the laser resection procedure would subsequently be used to resect the median lobe of the prostate phantom (Figure 3). The resected time, weight of the resected tissues together with the weight of the cadaveric prostate before and after undergoing the robotic motion plan were recorded.

2.4 Measurement of Tissue Damage (Coagulation) and Removal (Vaporization) Lesions

To determine variables affecting the vaporization and coagulation lesions, tissue samples were irradiated and the vapor-

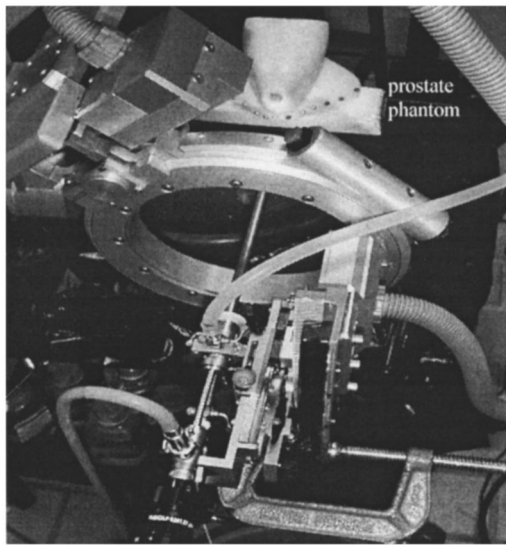


Fig. 3 Experimental setup for robotic laser resection of the median lobe (plan view).

ized depth (D) and width (W) were microscopically measured using a noncontact optical measuring machine (WEGU Messtechnik GmbH, Germany). Five repetitions of each run at 25 mm in length (L) were made, with mean values representing three readings for each run measured with an accuracy and resolution of ± 0.25 and $0.1 \mu\text{m}$, respectively. Regions of thermal damage were identified under normal light by the visible blanching and reduction of pigmentation. Blanched regions of coagulated depth (C_d) and width (C_w) were measured using the imaging system previously described. The volumes of tissue vaporized and coagulated (Figure 4) were calculated based on a semiellipsoidal^{28,30} cross section

$$\text{Volume of tissue vaporized} = \frac{WDL\pi}{4}, \quad (1)$$

$$\text{Volume of tissue coagulated} = \frac{L\pi}{4} [2C_w(D + C_d) + WC_d]. \quad (2)$$

2.5 Statistical Analysis

A second order analysis of variance was used in the statistical analysis of the experiments. The two-level factorial design (Design Expert® Software, Stat-Ease® Inc.) was used to ana-

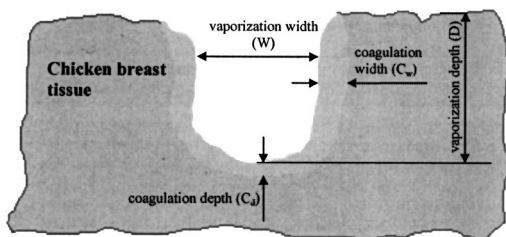


Fig. 4 Location of thermal effects (vaporization and coagulation) inside the chicken breast tissue.

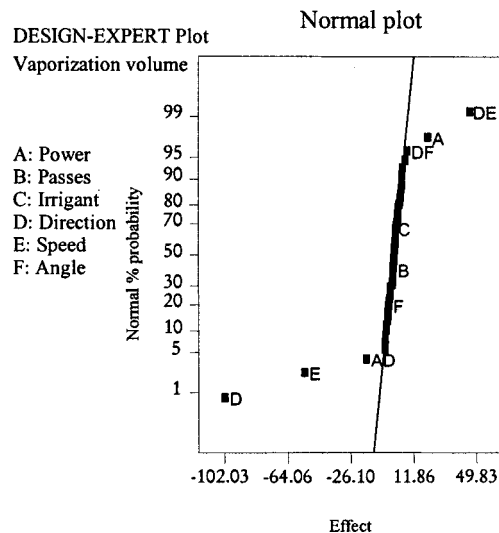


Fig. 5 Effects of different parameters affecting tissue removal in the longitudinal motion (chicken breast tissue).

lyze the effects each parameter has on the volume of tissue vaporized and coagulated. In the two-level factorial design, the effects were studied when each parameter changes from one level to another level. The central composite design in the response surface method was used to study the relationship between power and speed of lase with the volume of tissue vaporized and coagulated in the longitudinal and transverse motion.

3 Results

3.1 Gross Appearance of Lesions

The lesions produced on the chicken breast tissue were semiellipsoidal craters with a significant tissue defect due to vaporization, carbonization of the floor and a surrounding rim of blanched, coagulated tissue. The volume of vaporized and coagulated tissue varied with the irrigant flow rate, fiber/tissue angle of inclination, number of passes, speed, power and direction of lase. In the longitudinal motion, the chicken breast tissue was irradiated in the forward and backward direction for a distance of 25 mm, using the front end of the LaserTrode lightguide fiber tip. In the transverse motion, the tissue was irradiated for a similar distance in the clockwise and counterclockwise direction, using the lateral sides of the fiber tip. The depth and width of the vaporized and coagulated lesions were then measured and tabulated.

3.2 Effects of Different Parameters on Tissue Damage and Removal

Results from the two-level factorial design experiments revealed that the direction of lase D ($P < 0.0001$), has the highest effect on the volume of vaporization as the fiber was irradiating the tissue in the longitudinal motion. Volume of vaporization (noted by the negative effect value in Figure 5) decreases sharply when the direction of lase changes from forward direction (high level) to backward direction (low level). Speed of lase E ($P < 0.0001$), at 1 mm/s (low level) and 3 mm/s (high level), and power of lase A ($P < 0.0001$), at 60 W (low level) and 100 W (high level) also contributes

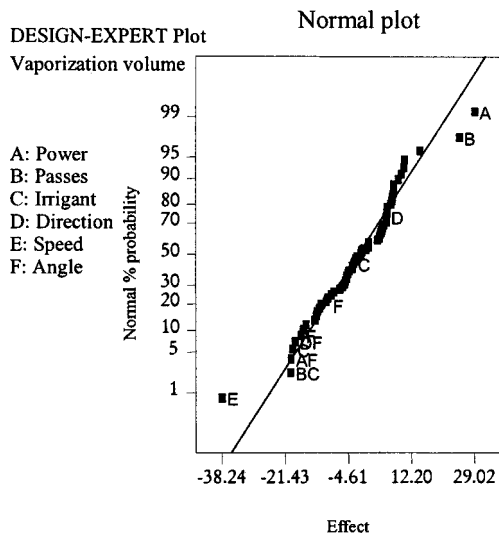


Fig. 6 Effects of different parameters affecting tissue removal in the transverse motion (chicken breast tissue).

significantly to the volume of vaporization. Increasing the fiber/tissue angle of inclination F , from 0° to 10° , causes a slight increase in the volume of vaporization while irradiating the tissue in the backward direction produces no increase at all in the forward direction. Both the increases in the number of passes and irrigant flow rate have no significant effect on the volume of vaporization of the tissue.

Similar to the longitudinal motion, the speed E ($P < 0.0001$) and power A ($P > 0.0004$) of lase contribute significantly to the volume of vaporization as irradiation of the tissue was carried out in the transverse motion. However, direction of lase D , irrigant flow rate C , and fiber/tissue angle of inclination F , have no appreciable effect (Figure 6). It was found that the effects of the different parameters on tissue damage (coagulation) correspond to that of tissue removal (vaporization).

3.3 Relationship Between Speed and Power of Lase in Tissue Removal

Parameters with significant effects were analyzed using the response surface method (Design Expert® Software, Stat-Ease® Inc.). A study was conducted to determine the relationship between speed and power of lase on the volume of vaporization when irradiating the chicken breast tissue in the forward direction (Figure 7). The power settings were 60, 80,

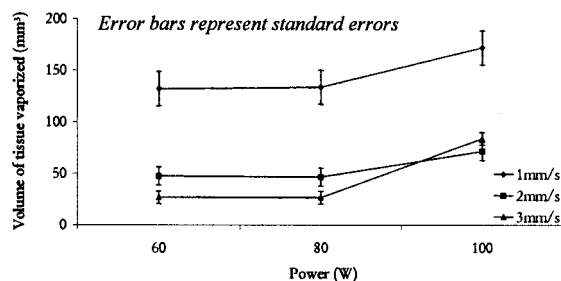


Fig. 7 Tissue removal in forward irradiation (chicken breast tissue).

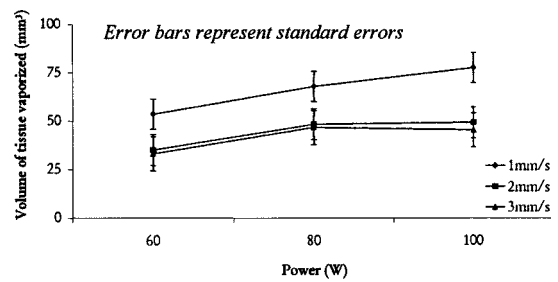


Fig. 8 Tissue removal in clockwise/counter-clockwise irradiation (chicken breast tissue).

and 100 W. With the increase from 60 to 80 W ($P < 0.0001$), there was no appreciable increase in the volume of tissue removed, but when the power setting was changed from 80 to 100 W ($P < 0.0001$), a minimum of 30% increase in tissue removal was observed. Conversely, when the speed of lase was increased from 1 to 2 mm/s ($P > 0.1144$), the volume of tissue removed decreased by approximately 90 mm³. An additional increase in the speed from 2 to 3 mm/s ($P < 0.0001$) resulted in only a slight reduction of approximately 10 mm³. An error in the fixing of the tissue to the holder during forward irradiation at 100 W and 3 mm/s may be the reason for a higher than normal value.

It was shown that tissue removal in forward irradiation has a maximum volume of 172 ± 9 mm³ of tissue vaporized compared to that of clockwise/counter-clockwise irradiation (Figure 8), which has a maximum volume of 78 ± 4 mm³. In clockwise/counter-clockwise irradiation, when the speed of lase was increased from 1 to 2 mm/s ($P > 0.3999$), the volume of tissue removed decreased by approximately 22 mm³. An additional increase in the speed from 2 to 3 mm/s ($P > 0.5037$) resulted in a further reduction of approximately 3 mm³.

3.4 Relationship Between Speed and Power of Lase in Tissue Damage

The volume of coagulation (needed for haemostasis) in the chicken breast tissue concurs with the volume of vaporization such that the volume of coagulated tissue increased with increasing power of the laser output between 60 and 100 W. Tissue damage in forward irradiation (Figure 9), with a maximum volume of 298 ± 11 mm³ at 100 W and 1 mm/s ($P < 0.0001$) is significantly higher compared to clockwise/counter-clockwise irradiation (Figure 10), which has a maximum volume of 104 ± 11 mm³ ($P > 0.0061$). The surrounding

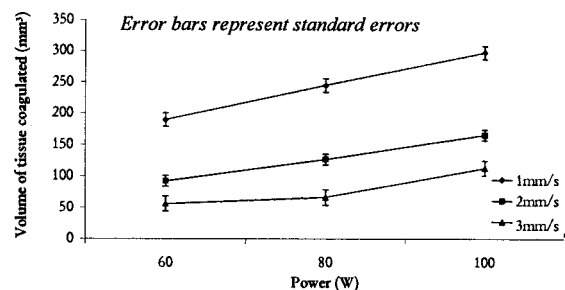


Fig. 9 Tissue damage in forward irradiation (chicken breast tissue).

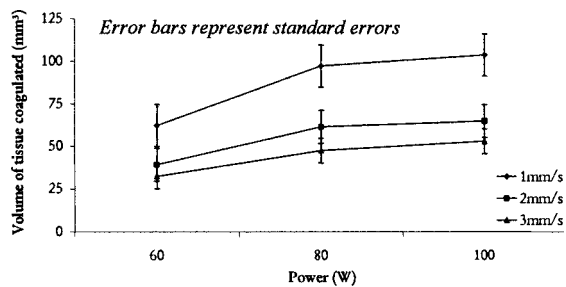


Fig. 10 Tissue damage in clockwise/counterclockwise irradiation (chicken breast tissue).

coagulation zone was found to be within a depth of 2 mm from the tissue surface of the incision. The width of the coagulated lesion was found to be approximately the same as the depth of the lesion.

3.5 Tissue Removal in Human Cadaveric Prostate

The vaporization characteristics were well matched between the chicken breast tissue and human cadaveric prostate. In forward irradiation of the cadaveric prostate tissue (Figure 11), the second increase in power setting from 80 to 100 W produces an average of 37% more vaporized volume than the first increase in power setting from 60 to 80 W. On the other hand, the second increase in the speed of lase from 2 to 3 mm/s yields, on the average, 46% less vaporized volume than the first increase from 1 to 2 mm/s. Operating under similar power and speed, forward irradiation of the prostate tissue was found to be capable of generating approximately 12% more of the vaporized tissue than clockwise/counterclockwise irradiation (Figure 12). Correlating chicken breast tissue with the human cadaveric prostate tissue, the mean difference in the volume of tissue vaporized is 5.8% and 33.9% in the forward and clockwise/counterclockwise direction, respectively.

3.6 Effectiveness and Feasibility of Robotic Laser Resection of the Prostate

The robotic lasing sequence in the motion plan begins by irradiating the enlarged lobe at the 6 o'clock position in the forward direction from the verumontanum to the bladder neck for a number of passes until the required depth is attained (Figure 13). The increment of the depth of lase after each pass is carried out by the increase in the arc angle of the R_1 axis after irradiating the tissue in the forward direction. Following

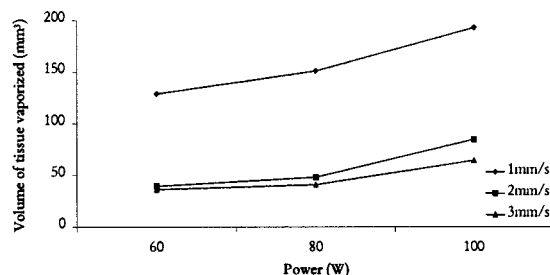


Fig. 11 Tissue removal in forward irradiation (human cadaveric prostate).

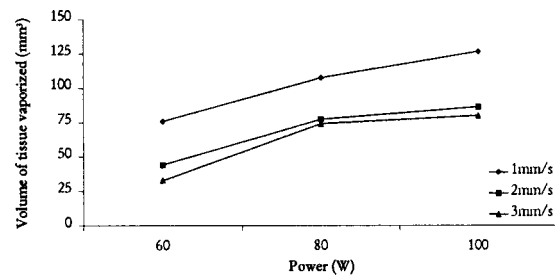


Fig. 12 Tissue removal in clockwise/counterclockwise irradiation (human cadaveric prostate).

the completed number of passes in the forward direction, the LaserTrobe lightguide fiber tip is positioned at the base of the enlarged lobe and irradiation performed in the clockwise and counterclockwise direction between 5 o'clock and 7 o'clock position using the R_2 axis (Figure 14). The fiber tip is moved forward incrementally by 2 mm using the L_2 linear axis before proceeding to the next sequence of irradiation in the clockwise and counterclockwise direction. The result from the robotic procedure will be an ellipsoidal or barrel-shaped cavity. The weight of the resected tissue fragments was found to be 2 g. The weight of the median lobe cadaveric prostate stands at 9 g before and 4 g after undergoing the robotic motion plan. Total resected weight, assuming negligible desiccation, is therefore 5 g with 3 g of the tissue being vaporized by the application of the laser thermal energy. This is in accordance to the latest finding by Mackey²² stating that approximately 50%–60% of the resected tissues were vaporized. The total resected time is 12.5 min, yielding an effective time of 150 s to resect 1 g of the prostate. This is comparable to the Gilling¹⁸ recorded effective resection time of 149 s per gram. Eichenauer²⁶ in his latest finding reported a lower effective resection time of 111 s per gram using his specially designed laser resectoscope. In both the Gilling and Eichenauer studies, a steep learning curve has first to be overcome. Relating HoLRP with the “gold” standard of TURP, Wong³² from Singapore General Hospital reported an effective resection time of 111 s to electrosurgically resect 1 g of the prostate (Table 1). It needs to be emphasized that since

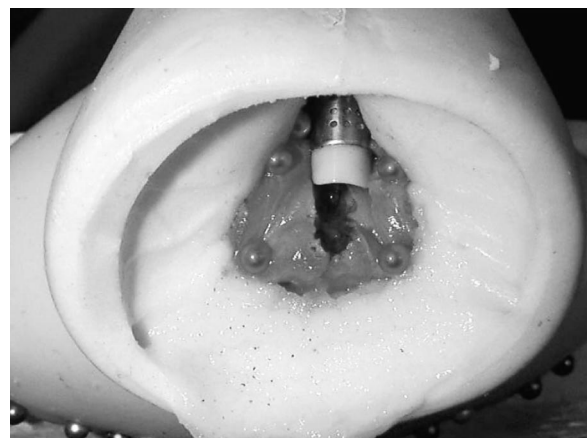


Fig. 13 Forward irradiation of prostate phantom (with human cadaveric prostate as the median lobe).

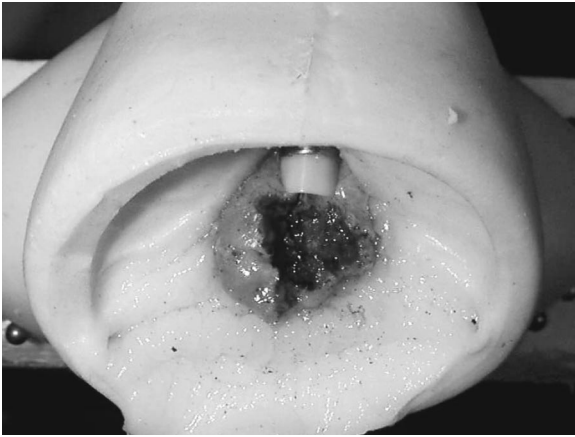


Fig. 14 Clockwise/counterclockwise irradiation of prostate phantom (with human cadaveric prostate as the median lobe).

only the median lobe and not the whole prostate was resected for the experimental study, the total resected weight of 5 g was expected to be grossly below that recorded by the other authors. Although in the referred publications by the other authors, no information was given pertaining to the inclusion of nonresection activities in the mean resection time, but in most clinical setting, the total time of the procedure includes the time taken for haemostasis and for the removal of tissue.

4 Discussion

Careful analysis of the efficacy, risks and associated complications of surgical treatment for BPH has encouraged the trend towards minimally invasive therapies. The need for simpler, less morbid and more cost-effective forms of treatment compared to TURP has, over the last decade, led to the emergence of various new minimally invasive modalities. These modalities include transurethral microwave therapy,³³ transurethral needle ablation of the prostate,³⁴ interstitial laser therapy,³⁵ side-firing Nd:YAG laser prostatectomy,³⁶ holmium laser resection of the prostate³⁷ and electrosurgery using new electrical generators or resection loops (VaporTrode,³⁸ VaporCut,³⁹ Wedge). Presently in the development phase, transurethral robotic laser resection of the prostate is aiming to provide an effective and efficient assistance to surgeons during surgery. The concept is promising and is a logical extension of existing laser resection principles like the HoLRP. However, there is a lack of data on parameters influencing the desired tissue effects. For the concept to

materialize, the parameters that affect this procedure were objectively examined and a method to quantify tissue damage and removal by contact laser coagulation and vaporization was described.

4.1 Forward Irradiation

The total volume of vaporized tissue in the forward direction was found to be 50 times ($P < 0.0001$) greater than in the backward direction. With direct irradiation in the forward direction, the volume of vaporized chicken breast tissue was 38% greater than irradiation in the clockwise/counterclockwise direction. The volume of coagulated tissue was 58% higher in the former than in the latter. In normal surgical practice using end-firing laser resection techniques, fiber/tissue angle of inclination between 30° and 80° was commonly used during backward irradiation that might injure the urethra or sphincter.¹⁰ Forward irradiation is consequently favored but, owing to ambiguous visual perception and lack of hand-eye coordination, it was observed experimentally that manual manipulation of the resectoscope to move the fiber forward was extremely tedious causing the fiber tip to be frequently ‘buried’ within the tissue. A controlled motion device, which has the ability to vaporize the tissue in a forward direction to a precise depth, is therefore needed. Inclining the resectoscope from 0° to 10° would cause the end of the fiber tip to move vertically by 12 mm, which is sufficient for forward irradiation and, subsequently, resection of the median and lateral lobes.

4.2 Characteristics of the LaserTrode Lightguide

From the experiments, it was found that carbonizing the LaserTrode lightguide fiber tip produces an average increase of 250% in the volume of tissue vaporized. Carbonization of the fiber tip as recommended by the manufacturer is a needed procedure prior to surgery to induce strong absorption of the Nd:YAG laser. It is carried out by first activating the laser with 90 W of energy, and then contacting the fiber tip with the tissue until the tip illuminates. When the fiber tip illuminates, the quartz glass crystallizes and the surface becomes rough, enabling small carbonized particles to be trapped that hinders a percentage of the laser energy from transmitting through the fiber tip and irradiating the tissue (Figure 15). This subsequently causes a buildup of thermal energy, leading to the vaporization of the tissue when the thermal energy is greater than the bonding energy of the tissue molecules. It was postulated that the mechanism of vaporization occurs differently for both the forward and clockwise/counterclockwise irradiation.

Table 1 Summarized table of comparison of different laser prostatectomy techniques with TURP on human prostates. It is noted that the robotic LRP experiments were conducted on human cadaveric prostate.

	HoLRP (Gilling)	HoLRP (Eichenauer)	Robotic LRP	TURP (Wong)
Resection weight (g)	21	31.3	5	24.2
Resection time (min)	52	58	12.5	44.8
Effective resection time (s/g)	148.57	111.18	150.36	111.07

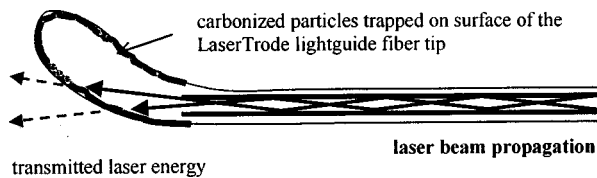


Fig. 15 Beam propagation of a carbonized fiber tip.

tion. During clockwise/ counterclockwise irradiation, tissue vaporization occurs on the sides of the LaserTrode tip sustained solely by the carbonized layer. However, during forward irradiation, the laser beam propagates out from the end of the fiber tip and comes in direct contact with the experimental tissue. This direct laser irradiation enhanced by the carbonized layer creates a larger volume of vaporization compared to the clockwise/counterclockwise irradiation. The difference in the mechanism of vaporization could also adequately explain the difference in the vaporization behavior of the forward and clockwise/counterclockwise irradiation with increasing irradiation speed and power for both the chicken breast tissue and human cadaveric prostate (Figures 7, 8, 11, and 12).

The symmetrically shaped LaserTrode lightguide fiber tip produces similar vaporization and coagulation volume while irradiating the tissue in the clockwise and counterclockwise direction ($P < 0.0001$). Due to the unique characteristics of the fiber tip, carbonization on the floor of the lesion produces no significant reduction in the efficiency of further vaporization of deeper tissues. No excessive accumulation of tissue was observed on the fiber tip, enabling a more constant depth of vaporization throughout the entire length of incision. In a single pass of a set depth of 2 mm, the vaporized and coagulated depth achieved by the LaserTrode lightguide was 1.6 ± 0.5 and 0.9 ± 0.5 mm, respectively. This uniformity in tissue vaporization is important, as controllability in the amount of tissue removed is desired in the procedure for transurethral robotic laser resection of the prostate. In comparison, Eichenauer¹⁰ in his experiment recorded the depth of cut achieved in a single pass with a holmium laser at 5–8 mm using a setting of 4 J and 10 Hz. With this laser system, precise and uniform incisions with low thermomechanical damage were achieved *in vitro* and the best healing response could be expected.⁴⁰

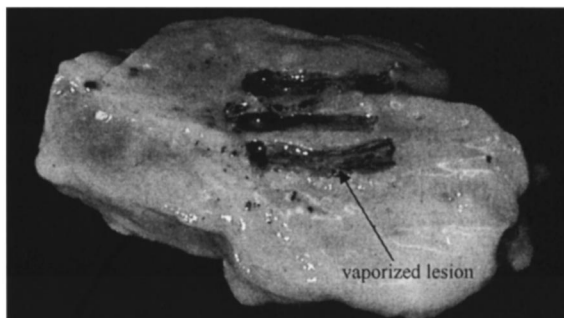


Fig. 16 Vaporized lesion on the dissected surface of the prostate (approx. 40 mm×40 mm×20 mm).

4.3 Vaporization Effects with the Human Cadaveric Prostate

Studies showed that laser vaporization in human cadaveric prostate, measuring approximately 40 mm×40 mm×20 mm (Figure 16), and chicken breast have similar qualities. Speed and power of laser were the main parameters influencing the desired tissue defects, quantified by the volume of tissue vaporized and coagulated. In forward irradiation, a decrease in 1 mm/s of the speed of laser produces an average increase of 75% in the volume of tissue vaporized compared to clockwise/counterclockwise irradiation. Conversely, an increase in 20 W of the forward lasing power produces an average increase of 57% in the volume of tissue vaporized. The speed of laser is therefore a significant parameter in optimizing the amount of tissue removed when conducting forward irradiation.

5 Conclusion

Still in the process of development, the transurethral robotic laser resection of the prostate was designed to be a treatment modality for providing an effective and efficient treatment for symptomatic bladder outflow obstruction from BPH. This present study has established several parameters using chicken breast tissue and human cadaveric prostate for effective transurethral robotic laser resection of the prostate. Results from 246 experimental runs showed that settings for the speed and power of laser are the most significant parameters in affecting the amount of tissue damaged and removed. Using the LaserTrode lightguide to irradiate the tissue in the forward and clockwise/counterclockwise directions provides efficient, precise and uniform tissue removal. Optimum irradiation power of 100 W and speed of 1–3 mm/s were used, respectively, in the procedure of transurethral robotic laser resection of the prostate.

The final phase of the experimental study includes executing the motion plan of the robotic system in resecting human cadaveric prostate tissue fixed in an anatomically alike prostate phantom. It follows that this procedure, which uses an integrated system of laser, computer and robotics technology, can permit an equivalent degree of tissue removal rate to that of TURP and HoLRP.

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