Pathologic Analysis of Ex-vivo Plasma Energy Tumor Destruction in Patients with Ovarian or Peritoneal Cancer

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ABSTRACT

Background: Cytoreduction of all visible disease has been associated with improved survival in patients with advanced-stage ovarian or peritoneal cancer. This is best achieved by minimizing injury to normal tissues. We report on the tumor destruction potential, in an ex vivo model, of a novel energy source that uses an electrically neutral beam of pure plasma to vaporize tissue.

Study design: Tumors were harvested from patients undergoing primary surgical cytoreduction for ovarian or peritoneal cancer. Specimens were divided into 1 cm^3 sections and treated with pure plasma energy for 2 or 4 seconds using standardized power settings. Bright-field microscopy was used to measure the depth of tissue vaporization and lateral thermal damage (LTD).

Results: The mean tissue vaporization depth was 2.7mm ± 1.3mm (n=96). The LTD was minimal at all tissue interaction settings (0.13 mm ± 0.031 mm). The LTD was approximately 5% of the depth of tissue vaporization. Tissue interaction time was a more powerful of a predictor of vaporization than power. When tissue interaction time increased from 2 seconds to 4 seconds, depth of vaporization and LTD increased by 1.7 mm and 0.03 mm, respectively (P<0.001 for both). When power was increased from low settings to high settings, depth of vaporization increased by 0.6 mm (P=0.02) and LTD did not change.

Conclusions: Plasma energy can effectively vaporize ovarian and peritoneal cancer cells. Greater power and tissue interaction time results in more tumor vaporization while maintaining minimal LTD. This is an attractive characteristic of plasma energy that may be useful for eradicating tumor off of visceral surfaces.

BACKGROUND

- Surgical cytoreduction is a vital component in the management of advanced ovarian cancer.
- Maximal cytoreduction is traditionally performed with the intent to remove all large volume disease.
- "Optimal' cytoreduction is currently accepted as no remaining tumor nodule greater than 1 cm in maximal diameter.
- A growing body of literature has demonstrated a potential benefit for complete resection of all visible disease.[1]
- Various techniques of cytoreduction have been described. [2,3]
- Pure plasma energy is a new technology that may be useful for cytoreductive surgery.

OBJECTIVE

- To describe the tumor destruction potential of pure plasma energy to vaporize tissue in an ex-vivo model.
- To test the hypothesis that tissue interaction time is a greater determinant of tissue destruction than energy level.

METHODS

- Specimens were collected from a single comprehensive cancer center from February to June of 2007 under Institutional Review Board (IRB)-approved protocols.
- Cases included 4 women found to have pathologically confirmed invasive high-grade serous ovarian or peritoneal adenocarcinoma. All cases had stage IIIC or IV disease.
- Fresh omental tumors were obtained in the operating room and immediately processed .
- Specimens were divided into 1 cm^3 sections and treated with pure plasma energy using the PlasmaJet® (PlasmaSurgical, Roswell, GA) for 2 or 4 seconds using one of several standardized power settings at a distance of 1 cm.
- The power settings tested were 70%, 75%, 85% and 90%.
- Specimens were then bisected at the point of maximal tissue damage and stained with hematoxylin and eosin according to standard techniques.
- The depth of tissue vaporization was measured from the parallel surface of the tissue section to the point of deepest tissue destruction (Figure 1.)
- Lateral thermal damage was measured as the largest distance between the carbon eschar to the point of viable tissue cellularity.
- All combinations of tissue interaction time and power settings were repeated in triplicate for each patient specimen resulting in twelve data points for each combination of power setting and tissue interaction time.

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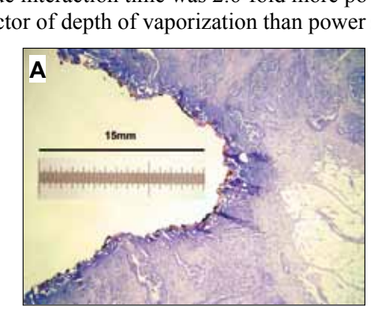
RESULTS

- Ninety-six specimens were analyzed.
- The tissue vaporization depth varied from 0.9 mm to 6.1 mm (mean, 2.7 mm; SD, 1.3 mm).
- The lateral thermal damage was minimal at all tissue interaction settings (mean, 0.13 mm; SD, 0.031 mm; range, 0.08–0.2 mm).
- The lateral thermal damage overall was approximately 5% of the depth of tissue vaporization (Table 2).
- Both tissue interaction time and power were associated with depth of vaporization.
- When power was increased from low settings to high settings, depth of vaporization increased by 0.6 mm, but adjacent thermal damage did not change.
- Depth of vaporization was more strongly correlated with tissue interaction time ($r^2 = 0.40$) than power ($r^2 = 0.06$).
- Tissue interaction time was 2.6-fold more powerful of a predictor of depth of vaporization than power setting.



- Fig. 1. Photomicrographs of representative sections demonstrating measurements of (A) tissue vaporization (x50) and (B) lateral thermal damage (x100) with more detail showed in (C, inset). Inset: x400.

RESULTS

Table 2. Depth of vaporization and lateral thermal damage for each combination of power and tissue interaction time.

Time	Power	Depth of vaporization (mm)*	Lateral thermal spread (mm)*
2 sec.	70%	1.56 ± 0.39	0.11 ± 0.023
2 sec.	75%	1.82 ± 0.45	0.11 ± 0.025
2 sec.	80%	2.15 ± 0.71	0.11 ± 0.027
2 sec.	85%	1.82 ± 0.51	0.12 ± 0.035
4 sec.	70%	2.67 ± 1.69	0.15 ± 0.028
4 sec.	75%	3.42 ± 0.93	0.15 ± 0.023
4 sec.	80%	4.00 ± 1.07	0.13 ± 0.033
4 sec.	85%	3.95 ± 1.37	0.15 ± 0.023

*Data is shown as mean ± standard deviation

CONCLUSIONS

- Plasma energy can effectively vaporize ovarian and peritoneal cancer cells.
- Greater power and tissue interaction time results in more tumor vaporization while maintaining minimal lateral thermal damage.
- An unexpected and remarkable characteristic of pure plasma energy is that as tissue vaporization increases, the lateral thermal damage remains relatively stable over a range of power settings and tissue interaction times.

SELECTED REFERENCES

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