Comparison of Procedure Costs of Various Percutaneous Tumor Ablation Modalities

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EXECUTIVE SUMMARY

- Microwave ablation, radiofrequency ablation, cryoablation, and irreversible electroporation are percutaneous ablation modalities commonly employed to treat tumors. The procedure cost of treating the same lesion with each of the four modalities is compared.
- A cost model was created for each ablation modality estimating the cost of treating a tumor based on the number of probes required, which is estimated by the tumor size. Total cost of treating a 3 cm kidney lesion with each modality was individually calculated.
- There was a strongly positive and statistically significant relationship between estimated cost based on the cost modules and actual cost for all procedures. The number of required probes is the dominant factor in determining the cost of an ablation procedure. The most expensive ablation modalities in decreasing order are irreversible electroporation, cryoablation, and microwave and radiofrequency ablations.

Healthcare costs have significantly increased over the past few decades leading to an ever increasing pressure to contain cost. Basic to cost containment is the fundamental understanding of the cost of every medical intervention. There are multiple ablation modalities that can be employed for percutaneous treatment of a tumor. The more commonly used modalities are radiofrequency ablation, microwave ablation, cryoablation, and irreversible electroporation. Many factors contribute to deciding which modality to choose including operators experience, efficacy, availability, and tumor characteristics such as size, type, and location. Cost of the procedure should also be an important factor in choosing a treatment. This is less commonly discussed and even less commonly known.

A point of inconsistency and occasionally confusion is how healthcare finances are reported; cost versus charge versus reimbursement. The cost of a procedure is the sum of the fixed and variable expenses associated with the procedure. The charge is an amount that a healthcare institution bills for a procedure, and is always higher than the cost. This is typically based on a rough estimate of the cost multiplied by a desired profit factor, typically between 2% and 4%. This is occasionally referred to as the cost to the health insurance. Logically, reimbursement is the amount of money that the healthcare institution receives in payment for the treatment rendered. This study focuses on cost, which is occasionally referred to as the cost to the hospital. Charge or reimbursement will not be discussed.

It has been repeatedly shown that percutaneous ablation of tumors can be curative with recurrence rates similar to open tumor resection. This has been reported for a variety of tumors, for example: microwave ablation of liver lesions, irreversible electroporation of kidney and liver lesions, cryoablation of kidney tumors, and radiofrequency ablation of renal cell carcinoma.[1–6] The cost of percutaneous ablation of tumors with radiofrequency ablation and cryoablation is significantly less than that of intraoperative ablation procedures, as summarized in Table 1. There is no published data comparing the cost of intraoperative and

TABLE 1. Comparison of the Cost of Percutaneous Ablation (IR) to Open Ablation Procedures in the Operating Room (OR)

	Data collected	Cost		Charge	
		IR	OR	IR	OR
RFA Hepatocellular carcinoma (7)	2002–2008	$7186	$11 809		
RFA Liver metastasis (7)	2002–2008	$5768	$9882		
Cryoablation of kidney tumors (8)	2003–2007			$14 175	$23 618
Cryoablation of kidney tumors (9)	2004–2006			$9240	$32 900

RFA, radiofrequency ablation.
Hospital stay cost or charge was included in the calculations. To date, there have been no published studies that have analyzed or reported the finances of percutaneous irreversible electroporation or microwave ablation.

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There is a paucity of data in the literature regarding the cost of percutaneous cryoablation and radiofrequency ablation. Among the very few published journal articles, there is an inconsistency regarding the reporting of the cost, charge, or reimbursement for these procedures (Table 2). Most of the published data are more than 6 years old and the actual dollar figures are not necessarily reflective of current monetary values.

Furthermore, there has been no direct comparison of the costs of ablation modalities. There are myriad factors contributing to the differences between the costs of similar procedures performed by different institutions, which renders comparison of the cost less reflective of the true differences in the procedure cost and more reflective of inter-institution variability. Therefore, comparison of the cost of cryoablation and radiofrequency ablation performed by different institutions is not necessarily a valid comparison unless the technique and workflow are the same.

The purpose of this study is to compare the procedure cost of treating the same lesion with four ablation modalities in a single institution: cryoablation, radiofrequency ablation, microwave ablation, and irreversible electroporation.

TABLE 2. Reported Average Cost, Charge, and Reimbursement for Percutaneous Treatment of Liver and Kidney Tumors by Radiofrequency Ablation (RFA) and Cryoablation*

	Data collected	Cost	Charge	Reimbursement
RFA hepatocellular carcinoma (7)	2002–2008	$7186		$7635
RFA liver metastasis (7)	2002–2008	$5768		$4329
RFA hepatocellular carcinoma (10)	2012			$9361
RFA primary liver tumors and metastasis (11)	1998–2000			$4322
Cryoablation of metastasis from NSCLC† (12)	unknown§		$11 000	
Cryoablation of metastasis from RCC‡ (12)	unknown§		$12 800	
Cryoablation of kidney tumors (8)	2003–2007		$14 175	
Cryoablation of kidney tumors (9)	2004–2006		$9240	$4134

NSCLS, non-small cell lung cancer; RCC, renal cell carcinoma.
*It is unclear if the hospital stay charge was included in the calculations for Shetty et al and Bang et al (12 and 13). Hospital stay cost or charge was included in the remainder of the calculations.
†This study reported cost of treatment of various NSCLC metastases to the lung, liver, adrenal glands, and paraaortic region.
‡This study reported cost of treatment of RCC metastasis to the nephrectomy bed, adrenal glands, paraaortic region, lung, bone, and peritoneum.
§The time and duration of data collection was not reported. The article was published in 2012.

Materials and Methods

Four cost models were developed, one for each ablation modality, estimating the cost of treating a hypothetical 3 cm kidney lesion. For the purpose of developing the cost models and based on our institution's protocol, the following are fixed or assumed to be similar in every case:

- All procedures are performed under general anesthesia (institutional protocol).
- Every patient has a 23 hour observation stay in the hospital after the tumor ablation.
- The computed tomography (CT) scanner and procedure room personnel are booked for 4 hour blocks for each procedure (institutional protocol).
- The CT scan procedure room is not used for other procedures even if the ablation procedure takes less than 4 hours.

The interventional radiologist is booked for 5 hours for every procedure. In our institution, the interventional radiologists are employees of the health system (integrated group practice).

The operation process of each ablation procedure was mapped out from presentation to our institution to discharge from the hospital following 23 hour observation. A list of materials and equipment required was compiled. Personnel time and contribution were also documented. The operation process map and the lists of materials, equipment, and personnel contributions were verified with the interventional radiology physicians, interventional radiology technologists, and sales representatives from the ablation companies. Costs were calculated with the assistance from the institution's finance department, which calculated direct fixed, indirect fixed, and variable costs. Follow-up and clinic visits were excluded from the analysis because they were the same across modalities.

The cost models were built with flexibility of changing the number of probes to calculate the cost of treating various lesions. Different size lesions will mainly differ based on the number of ablation probes required for treatment. As previously explained, anesthesia, CT scanner time, and other factors are similar regardless of the lesion. Therefore, when the number of required probes is determined in advance, it can be inputted into the model and the cost will be estimated.

Independently, 69 cases of various percutaneous ablations that were performed by the division of interventional radiology for the treatment of a variety of lesions from July 2010 to March 2012 were identified retrospectively (26 microwave ablation, 11 radiofrequency ablation, 27 cryoablation, and 5 irreversible electroporation). The cost of each procedure was determined by the hospital's finance department. This number was later compared with the estimated cost based on the modules developed.

TABLE 3. Common Costs for Percutaneous Microwave Ablation, Radiofrequency Ablation, Cryoablation, and Irreversible Electroporation Procedures for Treating Any Lesion.

Equipment, supply, and personnel	Cost
Preoperative & postoperative nursing	$231
General Anesthesia	
Anesthesia supplies	$890
CRNA	$825
MDA	$743
CT scan technologists	$458
CT scanner equipment	$680
Interventional radiologist (MD)	$1385
IR small procedure tray	$32
IV contrast, injector, syringe	$30
23-hour post procedure observation (room and board only)	$610
Miscellaneous supplies (syringe, gown, etc.)	$100
TOTAL	**$5984**

CRNA, Certified Registered Nurse Anesthetist; CT, computed tomography; IR, interventional radiology; IV, intravenous; MDA, anesthesiology physician.

TABLE 4. Modality Specific Cost for Treating a 3cm Kidney Lesion.

Equipment, supply, and personnel	Cost
Microwave Ablation	
Common cost of procedure*	$5984
V-tube	$199
Microwave Antenna†	$1940
Total	**$8123**
Radiofrequency Ablation	
Common cost of procedure	$5984
Ablation Probes‡	$2305
Total	**$8289**
Cryoablation	
Common cost of procedure	$5984
Ablation Probes§	$3900
Total	**$10, 103**
Irreversible Electroporation	
Common cost of procedure	$5984
Ablation Probes‖	$7000
Total	**$12, 984**

*Common costs of the procedures are the same independent of the ablation modality or lesion; this cost is detailed in Table 3.
†Typically, 1 microwave antenna is required for treating a round 3 cm lesion.
‡Typically, 1 radiofrequency probe is required for treatment of a 3 cm lesion.
§Typically, 3 cryoablation probes are required for a 3 cm lesion.
‖Typically, 4 probes are required for a 3 cm lesion.

For each procedure, the finance department calculated the direct and indirect fixed and variable costs including, but not limited to, direct fixed physician labor, direct fixed patient related labor, direct fixed external services, direct fixed non-patient labor, support services overhead, malpractice, graduate medical education expenses, department overhead, direct variable patient related labor, direct variable medical supplies, direct variable physician labor, direct variable pharmaceutical, and corporate offices overhead. Again, all personnel involved in the care of the patient and performing the procedure are employees of the health system. The ablation equipment is provided by the suppliers at no additional cost beyond the cost of the ablation probes.

An independent statistician utilized the nonparametric Spearman's rank correlation coefficient to quantify the strength and directionality of the relationship between the estimated cost and the actual cost. Statistical significance was set at $P < 0.05$. Analyses were done using SAS 9.2 (SAS Inc, Cary, NC, USA). Institutional review board approval was obtained for the study.

Results

The cost of treating the presumed 3 cm kidney lesion is $8123 for microwave ablation, $8289 for radiofrequency ablation, $10,103 for cryoablation, and $12,984 for irreversible electroporation. The common cost of the percutaneous ablation procedures is detailed in Table 3. The modality specific costs are summarized in Table 4.

Sixty-nine tumors that were treated with percutaneous ablation procedures were reviewed. Characteristics of these tumors including size, location, and number of probes required for treatment are listed in Table 5. The actual mean cost of treating these lesions is $9996 for microwave ablation, $9226 for radiofrequency ablation, $9408 for cryoablation, and $13,366 for irreversible electroporation. Table 6 details the mean actual cost and mean estimated cost of all four procedures and each specific procedure and their standard deviations.

There is a strongly positive and statistically significant relationship between estimated cost and actual cost for all procedures (r 0.47, $P < 0.001$). The Spearman's rank correlation coefficients (r) describe the relationship between the estimated cost and the actual cost. Correlation coefficients can range from –1 to 1, with a negative correlation indicating that when one variable increases the other decreases, and a positive correlation indicating that when one variable increases the other also increases.

Discussion

There is a large difference in the procedure cost of ablation modalities. Although, microwave and radiofrequency ablations are fairly similar in cost, cryoablation is approximately $2000 more expensive than the preceding two modalities. Irreversible electroporation is the most expensive ablation procedure: approximately $2800 more expensive than cryoablation.

TABLE 5. Actual Tumors Treated with Percutaneous Ablation Procedures.

	Microwave ablation	Radiofrequency ablation	Cryoablation	Irreversible electroporation
Independent procedures	26	11	27	5
Average tumor size	3.2	2.9	2.3	2.7
Standard deviation of tumor size	1.3	1.1	1.1	0.7
Location	Liver (23), lung (1), adrenal gland (1), retroperitoneal mass (1)	Liver (9), bone (2)	Kidney (22), lung (1), liver (1), bone (1), chest wall (1), periaortic lymph node (1)	Liver (3), kidney (1), paraaortic lymph node (1)
Average probes utilized	1.8	1.1	2.6	4.2
Range of probes used	1–4	1–2	2–7	4–5

TABLE 6. Descriptive Statistics of Cost in Total and by Each Procedure

	N	Estimate Mean (SD)	Actual Mean (SD)
Combined cases	69	$10,029 (1,768)	$9922 (3,955)
Microwave ablation	26	$9982 (1,852)	$9996 (4,635)
Radiofrequency ablation	11	$8918 (1,491)	$9226 (3,950)
Cryoablation	27	$9833 (934)	$9408 (2,710)
Irreversible electroporation	5	$13,334 (783)	$13,366 (4,444)

SD, standard deviation.
The estimated mean costs were calculated by inputting the number of probes in the developed cost modules. The number of required probes was estimated based on the size of the lesion. Actual cost was calculated by the finance department.

The actual number of probes required depends on the shape of the lesion and its location. Microwave ablation lesions are, in our experience, less predictable than other modalities. The quoted ablation size also varies by manufacturer and probe model. The radiofrequency ablation system currently used most commonly in our practice typically allows coverage of a 3 cm round lesion with a single self-contained 3 electrode array. We typically reposition radiofrequency probes for larger lesions. Similarly in cryoablation, the actual number of probes required greatly depends on the shape of the lesion and its location. In our experience, for every 1 cm increase in diameter of a round tumor, an average of 1 additional cryoablation probe is required. We usually use a minimum of two probes. The irreversible electroporation control unit uses advanced computer modeling once the lesion size has been inputted to provide the user with multiple options for probe number and spacing. Like microwave and radiofrequency ablations, irreversible electroporation probes can also be repositioned for overlapping ablations.

The majority of the costs of ablation procedures are the same; this is largely

due to the protocols in our institution as well as the study design. Ablation probes are the single dominant factor affecting the cost of ablation procedures. A procedure that requires more probes will be more expensive. For a similar sized lesion, irreversible electroporation requires more probes than cryoablation, and cryoablation requires more probes than microwave or radiofrequency ablations.

There are a few limitations to this study. In our institution the CT scanner, procedure room personnel, and interventional radiologist are booked for a fixed time for all procedures regardless of the ablation modality, which makes the cost calculation less sophisticated. However, the actual time required for procedures may not necessarily be the same and different institutions may not allot a fixed time for each procedure. We perform all ablation procedures with CT scan guidance. There is variability in the imaging modality used for guidance among interventional radiologists in that some may use CT for cryoablation and ultrasound for radiofrequency ablation. We also perform all procedures under general anesthesia. There is no commonly accepted standard of care regarding anesthesia and variability exists between different centers for various ablation procedures. This study assumes similar types and rates of complications for the various ablation techniques, which is true in our experience but we have not measured it. Ablation equipment is provided at no additional charge to our institution. However, there are various methods of purchasing ablation equipment. Finally, this is a single institution study and both the absolute and relative costs may vary by institution. The allocation methods for indirect costs can vary substantially between institutions.

There are many factors contributing to the selection of an ablation modality for the treatment of a tumor. Factors other than cost including efficacy, risks, possible complications, tumor location, type, and size commonly have more important roles in determining the treatment of choice. Cost can be one of the more important factors in the utilization of an ablation modality, assuming that a lesion can be treated with multiple ablation modalities with similar efficacy.

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