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.1–4 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
percutaneous irreversible electroporation or microwave ablation.

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

<table>
<thead>
<tr>
<th>Data collected</th>
<th>Cost</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IR</td>
<td>OR</td>
</tr>
<tr>
<td>RFA Hepatocellular carcinoma (7)</td>
<td>2002–2008</td>
<td>$7186</td>
</tr>
<tr>
<td>RFA Liver metastasis (7)</td>
<td>2002–2008</td>
<td>$5768</td>
</tr>
<tr>
<td>Cryoablation of kidney tumors (8)</td>
<td>2003–2007</td>
<td>$14 175</td>
</tr>
<tr>
<td>Cryoablation of kidney tumors (9)</td>
<td>2004–2006</td>
<td>$9240</td>
</tr>
</tbody>
</table>

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.

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

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

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 scan 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.

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

CRNA, Certified Registered Nurse Anesthetist; CT, computed tomography; IR, interventional radiology; IV, intravenous; MDA, anesthesiology physician.
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 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.
Comparison of Procedure Costs of Various Percutaneous Tumor Ablation Modalities

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

<table>
<thead>
<tr>
<th>TABLE 5. Actual Tumors Treated with Percutaneous Ablation Procedures.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Microwave ablation</strong></td>
</tr>
<tr>
<td>Independent procedures</td>
</tr>
<tr>
<td>Average tumor size</td>
</tr>
<tr>
<td>Standard deviation of tumor size</td>
</tr>
<tr>
<td>Location</td>
</tr>
<tr>
<td>Average probes utilized</td>
</tr>
<tr>
<td>Range of probes used</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 6. Descriptive Statistics of Cost in Total and by Each Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N</strong></td>
</tr>
<tr>
<td>Combined cases</td>
</tr>
<tr>
<td>Microwave ablation</td>
</tr>
<tr>
<td>Radiofrequency ablation</td>
</tr>
<tr>
<td>Cryoablation</td>
</tr>
<tr>
<td>Irreversible electroporation</td>
</tr>
</tbody>
</table>

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.
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 ablational modalities with similar efficacy.

References


Dr. Amin Astani is a senior radiology resident at the Henry Ford Hospital in Detroit, Michigan. He obtained his MBA degree from Illinois Institute of Technology before finishing medical school at the University of Minnesota. He can be contacted at amina@rad.hfh.edu.

Manuel L Brown, MD, FACR, is a professor of radiology at Wayne State University School of Medicine and the Kovacs Chair of Radiology at Henry Ford Hospital and Health Network. He is Chair of the Henry Ford Medical Group Board of Governors and serves on the Henry Ford Hospital Board of Trustees and the Henry Ford Health System Board of Trustees. He is a past president of the American College of Radiology and was previously a professor at both the University of Pittsburgh and the Mayo Clinic.

Kay Steusloff, RN is revenue manager in the department of radiology at Henry Ford Hospital in Detroit, Michigan.

Acknowledgment: Special thanks to Dr. Todd Getzen in Division of Interventional Radiology for his guidance and to Meredith Mahan, MS, statistician at the Department of Public Health Science at the Henry Ford Health System, who performed the detailed statistical analysis.
Questions

Instructions: Choose the answer that is most correct.

1. Many factors contribute to deciding which modality to choose for percutaneous treatment of a tumor. Which of the following is less commonly discussed?
   a. Operators experience
   b. Availability
   c. Cost
   d. Efficacy

2. The amount that a healthcare institution bills for a procedure is known as the:
   a. Cost
   b. Charge
   c. Desired profit
   d. Reimbursement

3. According to Table 1, what is the cost of a percutaneous ablation (IR) of a RFA Liver metastasis?
   a. $5768
   b. $7186
   c. $9882
   d. $11,809

4. Regarding the cost of percutaneous cryoablation and radiofrequency ablation procedures there is an inconsistency regarding the reporting of the:
   a. Cost
   b. Charge
   c. Reimbursement
   d. All of the above

5. According to Table 2, what is the charge of cryoablation of metastasis from RCC:
   a. $9240
   b. $11,000
   c. $12,800
   d. $14,175

6. For this study, four cost models were developed estimating the cost of treating what hypothetical lesion?
   a. Liver
   b. Kidney
   c. Lymph
   d. Renal

Continuing Education

Comparison of Procedure Costs of Various Percutaneous Tumor Ablation Modalities

Home-Study Test

1.0 Category A credit • Expiration date 8-31-2016

Carefully read the following multiple choice questions and take the post-test at AHRA’s Online Institute (www.ahraonline.org/onlineinstitute)
7. Which of the following is NOT one of the fixed or assumed protocols of the study?
   a. All procedures are performed under general anesthesia
   b. Every patient has a 4 hour observation stay in the hospital after the tumor ablation
   c. The CT scanner and procedure room personnel are booked for 4 hour blocks
   d. The CT scan procedure room is not used for other procedures

8. Intervventional radiologists are NOT employees of the health system.
   a. True
   b. False

9. Which costs were calculated with assistance from the institution's finance department?
   a. Direct fixed
   b. Indirect fixed
   c. Variable costs
   d. All of the above

10. How many microwave ablations were performed between July 2010 and March 2012?
    a. 5
    b. 11
    c. 26
    d. 27

11. According to Table 3, CT scanner equipment costs for percutaneous microwave ablation, radiofrequency ablation, cryoablation, and irreversible electroporation procedures for treating any lesion is:
    a. $680
    b. $743
    c. $825
    d. $1,385

12. According to Table 4, the total cost of using cryoablation to treat a lesion is:
    a. $8123
    b. $8289
    c. $10,103
    d. $12,984

13. How many tumors were treated with percutaneous ablation procedures for the study?
    a. 54
    b. 69
    c. 73
    d. 81

14. According to Table 5, what was the average tumor size treated with microwave ablation?
    a. 2.3
    b. 2.7
    c. 2.9
    d. 3.2

15. According to Table 6, what was the actual mean cost of irreversible electroporation?
    a. $9226
    b. $9408
    c. $9996
    d. $13,366

16. There is a large difference in the procedure cost of ablation modalities. Which two are fairly similar in cost?
    a. Microwave and radiofrequency
    b. Radiofrequency and cryoablation
    c. Irreversible electroporation and microwave
    d. Cryoablation and irreversible electroporation

17. Which ablation modality uses advanced computer modeling once the lesion size has been inputted to provide the user with multiple options for probe numbering and spacing?
    a. Microwave
    b. Radiofrequency
    c. Irreversible electroporation
    d. Cryoablation

18. Ablation probes are the single dominant factor affecting the cost of ablation procedures.
    a. True
    b. False

19. For a similar sized lesion, which of the following ablation modalities requires the use of more probes than the others?
    a. Microwave
    b. Radiofrequency
    c. Irreversible electroporation
    d. Cryoablation

20. Which of the following modalities does the institution in this study use for guidance?
    a. Ultrasound
    b. CT
    c. MRI
    d. All of the above