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Clinical Study

A cost comparative study of Gamma Knife radiosurgery *versus* open surgery for intracranial pathology

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ABSTRACT

Resection is the traditional treatment for common intracranial pathologies including brain metastases, arteriovenous malformations (AVM), and acoustic neuromas. However, more recently Gamma Knife radiosurgery (GKRS; Elekta AB, Stockholm, Sweden) has emerged as an effective, alternative treatment modality. There are limited data investigating the cost effectiveness of these two treatment modalities. In this study, we compare the costs of GKRS and open surgical excision. This was a retrospective study including all patients at a single-institution across a 3 year period with at least 12 months of post-resection follow-up for brain metastases, acoustic neuromas, or AVM. The costs of care were then totaled and compared to known average costs for GKRS at the same institution. The average 12 month costs of treating patients with brain metastases, acoustic neuromas, and AVM using open surgery were USD$55,938, $67,538, and $78,332, respectively. The average 12 month costs of treating brain metastases, acoustic neuromas, and AVM with GKRS were USD$23,069, $37,840, and $46,293, respectively. This shows that GKRS was on average 58.8%, 44.0%, and 40.9% of the cost of open surgery for brain metastases, acoustic neuromas, and AVM, respectively. GKRS is a cost effective, first-line, alternative to open surgery for treatment of brain metastatic lesions, acoustic neuromas, and AVM in selected patients. This result conforms to previous studies, which also demonstrate that radiosurgery is the more cost-effective treatment for brain metastases and acoustic neuromas when patients are well suited for either approach. Further prospective studies are needed to show that this result is valid at other institutions.

1. Introduction

Neurosurgical excision is the conventional treatment for brain metastases, arteriovenous malformations (AVM), and acoustic neuromas [1–3]. However, Gamma Knife radiosurgery (GKRS; Elekta AB, Stockholm, Sweden) has become an alternative treatment modality for these conditions. In the treatment of brain metastases, surgical excision has value as a diagnostic and therapeutic tool [2]. In addition to enabling a histopathological confirmation of diagnosis, excision of brain metastases facilitates immediate symptomatic relief and decreased dependence on corticosteroids and antiepileptic medications [2]. However, studies have shown that GKRS alone and conventional surgical resection combined with whole brain radiation therapy (WBRT) have comparable benefits for selected patients [4]. Microsurgical resection and GKRS are also appropriate interventions for AVM. Stereotactic radiosurgery (SRS) is advocated for the treatment of higher grade AVM due to their greater surgical risk, while lower post-operative hemorrhage rates and improved obliteration rates render open surgery an attractive option for treating lower grade AVM [5]. Furthermore, GKRS has been deemed acceptable for the treatment of acoustic neuromas with surgical contraindications, and radiosurgery is less likely to result in facial weakness or other post-operative complications [6].

Treatments of brain metastases, acoustic neuromas, and AVM are fundamental components of neurosurgical care. For every patient diagnosed with a primary intracranial tumor, 10 patients are diagnosed with a brain metastasis [7]. Additionally, acoustic neuromas comprise 8–10% of primary intracranial tumors [8]. Costly treatment complications of AVM include intracranial hemorrhage and seizure, and 7.1% of surgical candidates and 5.1% of radiosurgical candidates for AVM treatment will develop permanent neurological deficits [9]. These figures are particularly impactful when viewed in the context of the progressive growth of medical expenditures in the USA. In the current healthcare landscape, physicians are under increased pressure to improve quality of and access to care, while simultaneously maximizing its cost-effectiveness. Given these realities, it becomes clear that the

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previously mentioned neurosurgical pathologies pose a daunting clinical and economic burden. This dilemma persists beyond the borders of the USA. The healthcare systems of developing nations, such as those in Sub-Saharan Africa, are often based on a fee-for-service model, which precludes larger out-of-pocket expenses typically associated with GKRS and other advanced neurosurgical technology [10]. Limited availability of SRS-trained neurosurgeons in these regions exacerbates this deficit [10]. However, research that demonstrates the favorable cost of SRS may facilitate increased access to advanced care in under-resourced areas.

Further research is necessary to determine whether resection or GKRS is the more economically effective treatment, since the analysis of cost-effectiveness of these treatment methods will occupy an essential role in future clinical decisions. To this end, the purpose of this study is to compare the direct costs of GKRS *versus* open surgery for the treatment of brain metastases, acoustic neuroma, and AVM at the University of Virginia (UVA) Health System. Our study will provide a preliminary determination of whether GKRS or open surgery should be the first-line treatment from an economic perspective.

2. Methods

Patients treated with open neurosurgery at the UVA for brain metastases, acoustic neuroma, or AVM beginning from the calendar year of 2011 and with at least 12 months of follow-up were included in this Institutional Review Board approved study. This yielded a total of 44 patients. Patients having GKRS as well as open procedures were excluded. Charges to patients from the University of Virginia Physician Group (UPG) and UVA Medical Center (MC) were obtained for 16 patients with brain metastases, 11 patients with acoustic neuromas, and 17 patients with AVM. UPG numbers included charges associated with provider services. MC numbers included facility fees, such as inpatient room and board charges, operating room charges, equipment laboratories, radiology services, pharmacy services, services of MC employees such as nurses, and outpatient facility and MC personnel fees. The actual cost of care in US dollars for UPG and MC at our institution is 30% of the charges to the patient; thus, the costs to the patient were multiplied by 0.3 to obtain the costs of care. The costs of care to the UPG and MC were then combined to obtain the total cost of care of the open procedure (Table 1).

The costs of care for resections were compared to a mean total of UPG and MC costs of care for GKRS for the same pathologies at UVA during the same time period (the cost of care was similarly calculated for GKRS by multiplying total cost to the patient by 0.3). Charges for GKRS are relatively stable and therefore an average cost for each pathology group was used. The costs of the post-procedure MRI and follow-up visit were included in the UPG and MC costs for patients undergoing open procedures. The average cost of a post-procedure follow-up visit including clinical consultations for the year was included in the UPG and MC costs for GKRS. The average cost of a post-procedure MRI was not included for patients undergoing GKRS; thus, the cost of an MRI at UVA, estimated to be $4000 per neuroimaging study, was added to the average total costs for each of the pathologies in GKRS groups (Table 2).

3. Results

At our institution, the average 12 month costs of care for treating brain metastases, acoustic neuromas, and AVM with open surgery were $55,938 (range: $24,609–218,362), $67,538 (range: $37,103–146,684), and $78,332 (range: $18,749–513,498), respectively (Fig. 1). The average 12 month costs of treating brain metastases, acoustic neuromas, and AVM with GKRS were $32,869, $29,698, and $32,039, respectively.

For brain metastases, GKRS was on average $23,069 less expensive than open surgery (58.8% of the cost of open surgery). For acoustic neuromas, GKRS was on average $37,840 cheaper than open surgery (44.0% of the cost of open surgery). Similarly, for AVM, GKRS was on average $46,293 less expensive than open surgery (40.9% of the cost of open surgery).

4. Discussion

4.1. General

Our analysis revealed that GKRS and the accompanying 12 month care associated with it were less expensive than a comparable approach with open surgery for the treatment of brain metastases, acoustic neuromas, and AVM. These results are consistent with previous reports in the literature, which suggests that radiosurgery is a less expensive treatment than open surgery [11,12]. Ott's analysis revealed that average hospital charges for

Table 1
University of Virginia Physician Group, Medical Center, and total costs of care to individual patients for open surgery

	Met UPG	Met MC	Met Total	AN UPG	AN MC	AN Total	AVM UPG	AVM MC	AVM Total
1	$5,776	$28,913	$34,689	$13,438	$35,826	$49,264	$9,611	$27,164	$36,775
2	$5,045	$36,601	$41,646	$18,828	$43,208	$62,036	$10,262	$50,943	$61,206
3	$5,235	$33,971	$39,206	$14,499	$38,922	$53,422	$6,492	$507,005	$513,498
4	$5,284	$21,921	$27,205	$24,663	$82,106	$106,769	$7,883	$36,931	$44,813
5	$5,161	$24,987	$30,148	$12,990	$38,733	$51,723	$12,250	$70,766	$83,016
6	$7,612	$63,775	$71,387	$10,755	$51,216	$61,971	$11,114	$47,159	$58,273
7	$3,051	$80,680	$83,731	$11,048	$34,644	$45,693	$15,171	$74,999	$90,170
8	$4,878	$213,484	$218,362	$13,630	$133,054	$146,684	$10,432	$33,256	$43,688
9	$5,466	$43,717	$49,183	$6,329	$43,845	$50,174	$6,437	$53,974	$60,410
10	$4,736	$43,657	$48,393	$14,369	$63,707	$78,076	$15,395	$87,935	$103,331
11	$5,174	$43,009	$48,182	$4,113	$32,990	$37,103	$5,036	$13,713	$18,749
12	$5,003	$36,512	$41,516	–	–	–	$6,870	$34,422	$41,292
13	$2,330	$23,204	$25,535	–	–	–	$5,853	$35,134	$40,987
14	$6,803	$35,201	$42,004	–	–	–	$5,660	$15,377	$21,037
15	$4,808	$19,801	$24,609	–	–	–	$5,767	$22,739	$28,506
16	$5,499	$63,707	$69,206	–	–	–	$9,820	$40,625	$50,445
17				–	–	–	$6,853	$28,602	$35,455
Mean	$5,116	$50,821	$55,938	$13,151	$54,386	$67,538	$8,877	$69,456	$78,332

Costs expressed in US dollars.
AN = acoustic neuroma, AVM = arteriovenous malformation, MC = University of Virginia Medical Center, Met = metastasis, UPG = University of Virginia Physician Group.