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CT for Headache: Cost/Benefit for Subarachnoid Hemorrhage

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Nationwide cost and benefit was estimated for performing computed tomography (CT) on headache patients in the hope of discovering a specific finding, subarachnoid hemorrhage. Case finding costs were estimated using a previously published survey of CT use at a university hospital where, of 258 headache patients scanned, two had subarachnoid bleeding due to ruptured aneurysms. The incidence and natural history of ruptured aneurysms from a large-scale clinical trial and the outcome of surgery from the recent literature were used in the calculations. The results ranged from a worst case calculation of $24,713/year and $543,688/person saved (ignoring all other diagnoses) to a best case calculation of $1,999/year and $43,975/person assuming that other positive diagnoses were of equal outcome to ruptured aneurysms. The analysis, using a technique recommended as a model for future determinations of this type, also demonstrated that a most important variable in determining costs is the case finding rate. If there is a need to improve the use of new diagnostic technologies, such as CT, concentration should be on the identification of the characteristics of high-yield patient groups.

In 1944, Dandy [1] published a monograph describing his surgical approach to ruptured intracranial aneurysms. By the late 1950s, surgery for ruptured aneurysms had become a common but controversial procedure. In 1960, McKissock et al. [2] reported on the results of 599 ruptured aneurysms and concluded that, with the exception of intracranial hematomas, surgery provided no increase in survival compared with conservative treatment (i.e., bed rest, sedatives, seizure precautions, etc.). As recently as 1974, the results of a large multicentered trial also questioned the value of direct surgical treatment [3].

In more recent years, improved surgical techniques combined with studies identifying low-risk patients and optimum timing of operation have increased enthusiasm for surgery. For selected patients, an aggressive operative approach is now widely followed that produces significant reductions in morbidity and mortality [4–8]. However, because of the long-standing controversy over surgery, a number of large scale clinical trials have compared conservative and medical approaches [9, 10]. As a result, substantial information now exists on the incidence and natural history of subarachnoid hemorrhages of all causes, including those associated with ruptured aneurysms.

We know that the annual incidence of subarachnoid hemorrhage is 16/100,000 (about 33,600/year in the USA [6]). About 54% (18,144) of these are secondary to a ruptured arterial aneurysm. Without treatment, 40% of aneurysm patients have recurrent bleeding within 8 weeks and 60% of these second hemorrhages are fatal. An aneurysm patient who survives the initial rupture and is treated conservatively has a 50% chance of surviving for 1 year [9, 10]. Therefore, the chief advantage of surgery is that it offers the patient definitive protection from a recurrent hemorrhage and its attendant risk of death or severe disability.

Another finding from these therapeutic trials is that one of the most important

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TABLE 1: **Clinical Classification of Subarachnoid Hemorrhage [7]**

Grade	Criteria
1	Headache
2	Moderate to severe headache with nuchal rigidity or cranial nerve palsy
3	Drowsiness, confusion, or mild focal deficit
4	Moderate to severe hemiparesis, stupor
5	Coma

factors influencing surgical results is the patient's medical condition, especially the neurologic deficit, when first seen clinically and at surgery. Patients with minimal signs and symptoms consistently have a significantly lower surgical morbidity and mortality [4–8].

In describing initial signs and symptoms, most authors use the classification of Botterell et al. [11] or the more recent modification of Hunt and Hess [7]. These classification systems rank patients from grade 1 (headache) to grade 5 (coma) (table 1). About 20% of patients are first seen in grade 1; the rest are divided about equally in the other four grades. If untreated, 89% of grade 1 patients will progress to grades 2–5 within 1 year [10].

There is seldom much difficulty clinically detecting grades 2–5. However, grade 1 patients are a diagnostic problem. In the past, a patient complaining of a sudden severe headache but without other symptoms or signs was either treated for headache or hospitalized for observation and possible lumbar puncture.

The introduction of computed tomography (CT) increased the diagnostic choices. Extravasated blood is easily recognized by CT and the location of the ruptured aneurysm may occasionally be predicted by its distribution into the subarachnoid space and adjoining brain [12, 13]. One study recommended the substitution of CT for lumbar puncture in possible ruptured aneurysm patients [14].

About 12 million visits to physicians each year are by patients complaining of headaches [15]. Whether or not to scan a headache patient is ultimately a clinical decision, based on the experience and best judgment of the examining physician. In many cases, the examining physician can rely on the history alone as evidence against a serious underlying disease. In others, a limited neurologic examination may give enough reassurance. However, the timing, character, history, and physical examination are not always definitive, and the physician must decide if CT is indicated.

With increasing economic pressure, how can physicians, economists, and other social observers determine the economic effects of physicians' actions? What are the economic consequences of using CT in patients with severe headache? How do the costs and benefits compare? Where could improvements be made?

Materials and Methods

We previously reviewed the recent experiences of physicians referring patients for CT scanning at George Washington University Hospital (GWUH) [16]. The results of our survey showed that when 258 headache patients were scanned, 20 clinically important diagnoses were detected, of which two were ruptured aneurysms. Further analysis of all ruptured aneurysm patients found during the study period revealed that GWUH physicians had a diagnostic yield of two (0.78%) of 258 patients with headache only (grade 1) and a combined diagnostic yield of 34 (24.3%) of 140 grades 2–5 patients (table 2).

TABLE 2: **Subarachnoid Hemorrhage Diagnosed by CT, 1977–1978 [16]**

Initial Symptom	Subarachnoid Hemorrhage Diagnosed by CT	
	No. Patients	Probability
Coma (grade 5)	4/56	0.07
Subarachnoid/subdural hemorrhage (grades 2–4)	30/84	0.36*
Stroke	6/356	0.02
Dementia	0/129	0
Headache (grade 1)	2/258	0.0078

* $P = 0.001$ (chi-square analysis).

Since a great deal of information existed on both the natural history and results of treatment of ruptured aneurysms, we decided to use our diagnostic yields and the current results with surgery to calculate the cost and benefits of scanning patients with headache in search of persons with subarachnoid bleeding due to aneurysms. The method used to find the diagnostic yields is described in detail elsewhere [16]. Briefly, during a 1 year study period at GWUH, all requests for CT scanning were prospectively placed in diagnostic categories according to the most specific initial sign or symptom. After scanning, a diagnostic yield (number of positive scans/total number of scans ordered) was computed for each category using a list of preselected positive clinically important CT findings.

During the study period there was no attempt to limit access to the scanner. Referrals for CT head scanning came from neurologists, neurosurgeons, internists, general surgeons, and six other specialty groups on a first come, first served basis. With the exception of scans obtained on an emergency basis, prior approval by an attending neurologist was unnecessary. We believe this open access policy is largely standard throughout the USA.

To complete this cost-benefit study, the 42 patients diagnosed by CT as having subarachnoid hemorrhage were followed for actual short-term outcome. In 36 of these (all but the six patients with stroke), a ruptured aneurysm was actually confirmed by angiography; 34 were initially seen in grades 2–5.

Results

Using these diagnostic yields and the 1977 average nationwide cost for CT study of $255 ($190 technical cost, $65 professional fee) [17], case finding costs for subarachnoid hemorrhage were then calculated at $32,895 for grade 1 patients and at $1,050 for grades 2–5. (Overhead and indirect costs are not considered in subsequent discussion.) These individual case finding costs were used to determine total nationwide CT scanning costs assuming two separate decisions (figs. 1–3). Decision 1 assumes that all patients with severe headaches will be scanned and that the diagnostic yield of scanning headache patients at GWUH is replicated nationwide. Decision 2 assumes that no patients with headache alone will be scanned and requires a second neurologic sign and/or symptom before a scan is ordered.

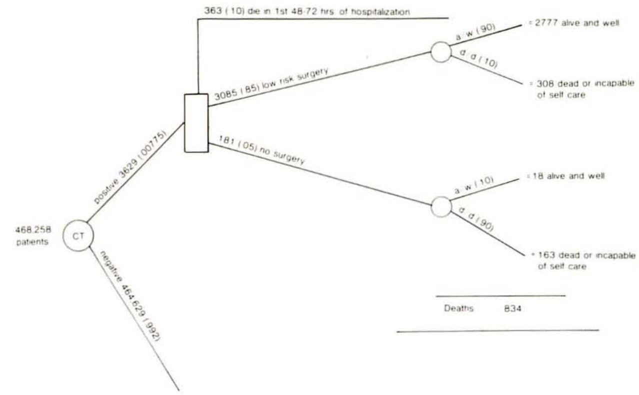

Fig. 1.—Results of benefit decision 1 for scanning all grade 1 patients.

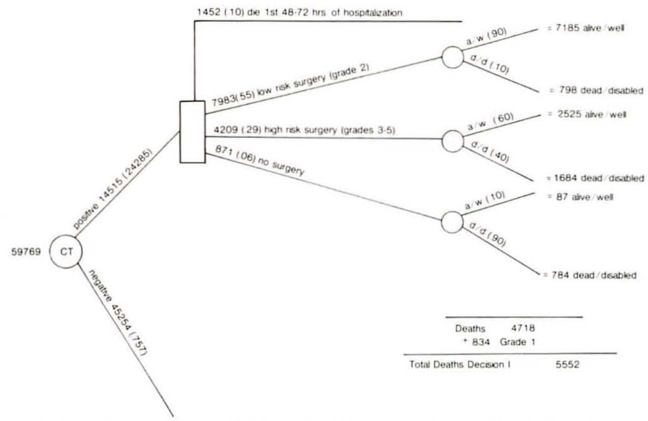

Fig. 2.—Results of benefit decision 1 for scanning grades 2–5 patients.

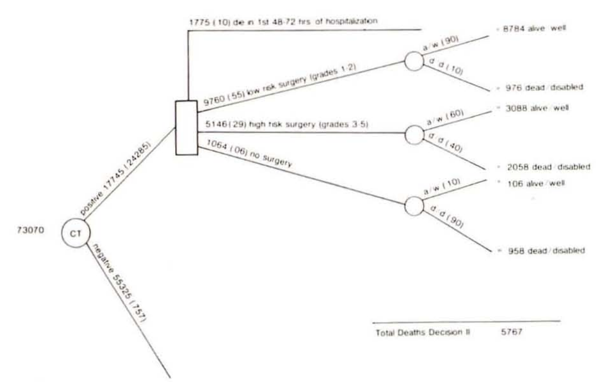

Fig. 3.—Results of benefit decision 2: scanning grades 2–5 only.

Using these two decisions, the incremental costs of scanning headache patients were determined. This determination was based on nationwide annual incidence figures and the natural history of bleeding due to ruptured aneurysms. The net incremental cost of scanning 468,258 headache patients to find the 3,629 bleeding aneurysm patients was $115,984,450 (table 3).

The total number of headache patients scanned under both decisions is based on diagnostic yield; that is, if two bleeding patients are found for every 258 patients scanned, then to detect the 3,629 (20% of 18,144) total grade 1 patients each year, 468,258 patients must be scanned. As is discussed later, small changes in the diagnostic yield can produce substantial differences in total costs and in the final cost-benefit calculation.

TABLE 3: **Costs of Scanning Versus Not Scanning Grade 1 Patients**

Calculation	Decision 1	Decision 2
Grade 1:		
Case finding cost	$ 32,895	...
× No. bleeding patients/year	3,629	...
Subtotal	$119,375,950	...
Grades 2–5:		
Case finding cost	$ 1,050	$ 1,050
× No. bleeding patients/year.	14,515	17,745*
Subtotal	$ 15,240,750	$18,632,250
Totals	$134,616,700	$18,632,250
Net incremental cost ($134,616,700 – $18,632,250)	$115,984,450	...

* Assumes that 89% of grade 1 patients deteriorate to a lower grade over 1 year.

TABLE 4: **Surgical Results in Bleeding Aneurysms**

Reference No.	No. Patients (% mortality†): Total	Group per [7] and [11]*	Grades 1–2	Grades 3–5
[4]	60	56	41 (12)	15 (27
[5]	250	231	112 (3)	119 (31)
[6]	62	62	39 (13)	23 (65)
[7]	275	156	129 (11)	27 (41)
[8]	100	86	58 (21)	28 (64)
Totals	747	591	379 (10)	212 (40)

* Patients reclassified for uniformity according to scale of Hunt and Hess [7] and Botterell [11].
† Includes surgical deaths and patients incapable of self-care.

To determine what this $116 million provides in terms of improved morbidity and mortality, outcomes were calculated for decisions 1 and 2. Figures 1 and 2 describe decision 1, in which all grades 1–5 patients are scanned. Figure 3 traces the outcomes under decision 2, in which only grades 2–5 patients are accepted for scanning.

We derived most of our 1 year outcomes and grades of patients at surgery from five recent large-scale studies of bleeding aneurysm patients that used comparable patient classification systems. These studies are summarized in table 4, and the outcomes in figures 1–3 combined these studies with the known natural history of ruptured aneurysm.

Because of the better operative results with grades 1 and 2 patients, there are 215 fewer total deaths under decision 1. This benefit is achieved by performing 1,308 more operations on grade 1 patients and 937 fewer high-risk operations on grades 3 and 4 patients. If we use the 1977 average nationwide charge and professional fee for arteriography, craniotomy, and 3 weeks hospitalization of $7,500 for the additional craniotomies and a total charge of $9,500 for the high-risk operations (an increase of $2,000 to account for 20 more hospital days), the net increase in surgical costs is $908,500. Total incremental costs for decision 1 versus decision 2 become $116,892,950.

TABLE 5: **Costs and Benefits of Decision 1 for Scanning 3,629 Grade 1 Patients and Influence of Alternate Cae Finding Rates**

Calculation	Case Finding Rate (Incidence)			
	1/258 (0.0039)	2/258 (0.0078)	3/258 (0.011)	20/258 (0.078)
Case finding cost*	$ 65,790	$ 32,895	$ 21,930	$ 3,290
No. scans required	935,309	468,258	312,038	46,826
Gross cost	$238,751,900	$119,375,950	$ 79,583,960	$ 11,937,570
Net cost of scanning and surgery†	$236,267,900	$116,892,950	$ 77,100,960	$ 9,454,570
No. lives saved	215	215	215	215
Cost/life saved	$ 1,098,920	$ 543,688	$ 358,609	$ 43,975
Cost/year of life saved	$ 49,951	$ 24,713	$ 16,300	$ 1,999

* Using $255/CT scan.
† Gross costs adjusted for the reduced amount of scanning among grades 2–5 patients and the increased costs of added surgery and hospitalization.

To better describe the total benefit, we know that while bleeding aneurysms occur from the late teens to age 70, the peak incidence occurs around the fifth to sixth decades [9, 10]. Life insurance mortality tables predict that a male or female who lives to be 55 will have 22 more years of life [18] (this assumes that the patients will not die from other cerebral aneurysms, polycystic kidney disease, or aortic coarctation). Therefore, by following decision 1, 215 individuals and 4,730 years of life are saved. At a total cost of $116,892,950, this means each year of life saved costs $24,713 and each person $543,688 (table 5).

Limits on Analysis

Our worst case calculation used a number of simplifying assumptions. Two of the most important were that CT scanning represents perfect information (i.e., no false-positive or -negative scans) and that if the patient does not have a subarachnoid bleeding, no other disease is present.

The effect of this latter assumption, that we are only screening headache patients for bleeding, has the effect of underestimating benefits relative to costs. Subarachnoid hemorrhage is obviously only one of many potential diagnoses physicians considered when referring headache patients for CT, and the characteristics of patients referred with a sudden severe headache separate them from other more chronic sufferers. Indeed, there were 18 other positive CT diagnoses made on the 258 headache patients. To be complete, each one of them should be separately analyzed for the expected results from tests done after CT as well as further treatment. The same is true for patients referred because of a presumptive diagnosis of subarachnoid hemorrhage who actually had other diseases. However, the number of possible outcomes combined with the difficulty of finding comparable and accurate outcome data for each diagnosis makes this calculation inaccessible.

One way of estimating the potential impact of this limitation is to calculate the cost-benefit ratio using the assumption that all 20 positive diagnoses obtained among the 258 headache patients had a response to medical therapy and outcome similar to bleeding aneurysms. We call this a best case calculation since few, if any, of the other diagnoses possible in headache patients (tumors, hydrocephalus, abscess) respond to therapy as well as ruptured aneurysms. As seen in table 5, the results of this best case calculation substantially lower the case finding cost and improve the cost-benefit ratio by a factor of 10. Because of the exponential nature of the cost-benefit curve, the costs become less pronounced as more cases are detected.

The sensitivity and specificity of CT can also be estimated. Using a high false-negative rate estimate for CT detection of subarachnoid bleeding of 10% (as suggested by two studies that looked at all grades of bleeding patients [12, 14]), the effect on the final cost-benefit conclusion is as follows. Assuming that the symptoms of grades 2–5 patients will prompt the diagnosis to be pursued regardless of the CT results, the effect of the false-negative rate is that 363 grade 1 ruptured aneurysm patients each year will be missed by CT. Eighty-nine percent or 323 will deteriorate during the year to grades 2–5 [10].

The effect of these delayed diagnoses is 22 more deaths will occur under decision 1. This increases the cost-benefit ratio to $27,530/year or $605,663/person saved. Thus, if the false-negative error rate remains at the 10% level, the cost per life saved increases by about 11% across all case finding rates.

To date, there are not any reports of a false-positive CT diagnosis of subarachnoid bleeding. Although it is unlikely this type of error will become a significant problem, its potential effect on our calculation can also be determined. If we assume a 10% false-positive rate, then every year under decision 1, 46,463 headache patients would have a false-positive CT scan indicating bleeding. Then, if each of these cases were hospitalized and underwent lumbar puncture, it would add about $10.5 million to total costs. This would make the final cost-benefit calculation $592,525/life saved. Of course, if false-positive results lead to hospitalization and angiography, not only would the total cost be increased but a small increase in mortality from angiography might also occur, further increasing cost per life.

In addition to the effects of other diseases and test errors, this calculation also does not consider the unknown cost of radiation exposure and the immeasurable but immense benefit of a true-negative finding to the patient concerned and frightened over the possibility of disease. This latter point is important to both clinicians and health planners. Since good medical practice includes reassuring patients concerning the absence of disease, the value of a true-negative test, although not explicitly stated, must be understood and considered implicitly when reviewing cost-benefit calculations. This calculation also assumes that the patient classification used by different observers is the same, that the observations on incidence and prevention are accurate, and that persons successfully treated for bleeding aneurysm will have a mortality equal to the general population.

Finally, it is important to return to the most important limitation of this study: the reliability of the case finding rate among grade 1 patients. The number of bleeding aneurysm cases found in our study, two, is not large enough to be viewed as a precise estimate of the exact incidence among patients with headaches. As is well known by clinicians, the character of a headache frequently associated with subarachnoid bleeding is sudden and severe, often characterized as "the most severe headache possible." The diagnostic yield of headache patients meeting this criteria should be substantially higher than two of 258. Because of this it may be more realistic to use the best case calculation of 20/258 as approximating the case finding rate, $43,975 as the cost/life saved, and $1,999 as the cost/year saved.

Discussion

Is life priceless? If it is, then our calculations are pointless. However, if there is a limit, an amount so great that we question whether a medical action is appropriate in a certain situation, then cost-benefit calculations can be useful. Although costs will never be the sole determinant in medical decisions, they can be incorporated into decision making.

How we view our best case estimate of $1,999/year of life saved depends on how it compares with other decisions. In a nationwide comparison of coronary care units, mobile coronary care units, and costs for cholesterol screening and education, Cretin [19] estimated that it costs from $269 (screening) to $3,141 (mobile coronary care units) to save 1 year of life from heart attacks.

Collen [20] found the cost of diagnosis under different schedules of physical examinations and mammography screening to vary from $12,480/cancer patient for a group unscreened previously to $18,193/cancer patient for clinical examinations and screening mammograms. The potential benefit of these various decisions was not estimated.

Compared with the $3,141 estimate of Cretin [19], $1,999 seems a small price for 1 more year of life. This benefit is even more pronounced since the natural history and prognosis of patients with their first myocardial infarction is substantially worse than that of patients with successfully treated ruptured aneurysms, in whom reoccurrence is low. It is difficult to compare our results directly with the Collen [20] breast cancer study because benefits were not estimated. However, his case finding costs, ($12,480–$18,193) are substantially higher than ours.

The large influence of the case finding costs on the final cost-benefit calculation is another striking conclusion from our study. Substantial changes in specificity and sensitivity of scanning, shifts between low- and high-risk surgery, and length of hospitalization do not greatly alter the final cost-benefit figure. But, as demonstrated in table 5, increasing the diagnostic yield by a small percentage (e.g., finding three bleeding aneurysm patients for every 258 patients scanned instead of two) can substantially reduce costs. Likewise a similar reduction of only one bleeding aneurysm patient doubles the cost per year of life saved. Because of the importance of the diagnostic yields to the final calculation it would be desirable to obtain a larger data set from other institutions on which to base these calculations. A similar survey reported from Peter Bent Brigham Hospital revealed no positive CT scans in 53 headache patients [21].

Assuming such diagnostic yields, major advances in the efficiency of CT scanning can best be achieved by better defining patient groups likely to benefit from its use *before* ordering the test. This is particularly true for patients with a less than 5% probability of positive results. Such improvements are likely to be much more effective at reducing costs than efforts aimed at improving use by patients declared abnormal once tested.

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