5.
The Cost Effectiveness of Digital Subtraction Angiography

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The final objective of a thorough cost and quality assessment of any new medical technology is to ascertain the degree of relationship between the incremental costs of the new procedure and the extent to which the prevention and/or treatment (cure) of the relevant diseases has occurred or is likely to occur. In this case study of digital subtraction angiography (DSA), the focus of inquiry is somewhat more limited. Although it would be ideal to be able to compare all technologies of all types relevant to cerebrovascular disease on the basis of their contribution to improvements in patient morbidity, mortality, disability, longevity, and productivity, the information needed for such an analysis simply does not exist. Thus, the conventional approach to cost effectiveness analysis for a diagnostic imaging technology is to compare the "cost per procedure" and the "cost per lesion found" between the new technology and one or more existing technologies (24,33).

In the case of carotid artery disease, a "significant lesion" is usually defined as arterial stenosis of 50 percent or greater. This is the approach taken in this analysis of the cost effectiveness of DSA. In other words, this analysis seeks to measure the "cost per unit of effectiveness" of DSA in comparison with conventional arteriography, a competing alternative technology with common objectives (8). It also reviews the existing cost effectiveness analyses.

REVIEW OF EXISTING STUDIES OF THE COST EFFECTIVENESS OF DSA

Two cost effectiveness studies of DSA have been performed (24,33). Each compared conventional arteriography with DSA in the evaluation of patients with transient ischemic attacks (TIAs). Freedman (33) limited his analysis to the cost of studies of the carotid arteries. The primary unit of analysis in both studies was the "cost per identified lesion"; Detmer and colleagues *(24)* also included a measure of "radiation dose per lesion found." The key assumption, monetary values, and findings from each study are listed in table *5-1*.

In these studies, the population to be studied with DSA is assumed to be approximately twice as large as the population currently examined with arteriography. These estimates are derived from a cooperative study of TIAs conducted in five academic medical centers *(102)*. Freedman (33) notes that the incidence of TIAs reported in the cooperative study appears to be low. He argues that incidence can range up to four or five times that level in a community with a large elderly population. It would appear, then, that the population at risk has tremendous implications for the overall costs of DSA imaging as a technological alternative to conventional arteriography.

Yield rates (the numbers of lesions found per population screened) are also widely variable, even for arteriography. Eisenberg and Nicklin (28) observed that abnormalities found in arteriographic studies ranged from 22-42 percent to 100 percent for TIA patients. This variability is due to the inclusion or exclusion of ulcerative lesions, differences in the populations screened, local differences in patterns of practice in certain medical specialties, and whether the findings were reported in the clinical or radiological literature. Detmer and colleagues *(24)* base their estimated yield of 75 percent for arteriography on the actual yield of that technology at the University of Wiscon-

Table 5-1 .—Data Used for Cost-Effectiveness Analysis of DSA

Assumptions	Detmer, et al. (1982)[a]	Freedman (1982)[a]
I. Patient population examined:		
A. Definite TIAs	8.4 TIAs/100 beds	5.4 TIAs/100 beds
B. Possible TIAs.	17.4 TIAs/100 beds	16.8 TIAs/100 beds
II. Yield rates:		
A. DSA	High = 75 percent Low = 25 percent	High = 80 percent Low = 40 percent
B. Arteriography	High = 75 percent Low = 25 percent	High = 80 percent Low = 40 percent
III. Cost/procedure:		
A. DSA	$ 225	$ 500
B. Arteriography	$1,120	$1,200
IV. Cost effectiveness (cost/lesion found)		
	Population examined	
Screening protocols	Low High	Low High
A. Arteriography only	$1,492	$1,500
B. DSA followed by arteriography if DSA is positive.	$1,438 $1,590	$1,825 $2,033
C. DSA, followed by arteriography in only 50 percent of positive DSA exams as a confirmatory measure	$ 936 $1,065	$1,225 $1,433
D. (1) DSA, followed by arteriography in only 10 percent of positive DSA exams (Freedman)	–	$ 775 $ 950
(2) DSA, followed by arteriography in only 5 percent positive DSA exams (Detmer. et al.)	$ 376 $ 512	—

[a]Full citations found in References Section.

SOURCE Office of Technology Assessment

sin Hospital; they assume that DSA accuracy is equal to that figure (adjusted for a 5-percent rate of technical failure of DSA). Detmer and his colleagues (24) noted, however, that DSA does not currently approach that level of accuracy for ulcerative lesions. The generalizability of this rate is quite limited, and the estimated yield rates for DSA means that the Detmer and the Freedman studies must be carefully interpreted. The same conditions will limit the accuracy of this cost effectiveness analysis of DSA in the diagnosis of cerebrovascular disease.

The validity of the estimated costs of DSA and arteriography are also subject to scrutiny. Detmer and colleagues (24) present no cost findings at all, but simply list the billed *charges* for these procedures at the University of Wisconsin Hospital. Further, costs in their analysis do not include professional fees (approximately *$150) (33).* Freedman (33) does not provide detailed estimates of the fixed and variable costs of DSA imaging, but only gives "point estimates, " rather than ranges, of cost effectiveness.

Interpretation of these studies is further complicated by the fact that the estimates are derived from operational costs in two large and innovative radiology practices, one of which is part of an academic medical center. These practices may reflect a very different cost experience from community hospitals and ambulatory sites, particularly with respect to the allocation of overhead costs.

NEW TECHNOLOGY AND PATTERNS OF MEDICAL PRACTICE: CRITICAL ASSUMPTIONS UNDERLYING AN ANALYSIS OF COST EFFECTIVENESS

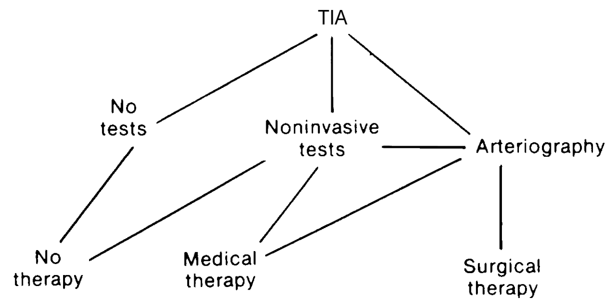
In order to investigate the cost effectiveness of a new diagnostic tool such as DSA, it is important to attempt to understand its potential role in the care of patients with TIAs or patients who may have had a completed stroke. It is essential that predicted changes in the process of health care delivery and its outcome be identified. Thus, a cost effectiveness analysis of DSA should proceed from a conceptual model of how this technology will "fit" with existing technologies and patterns of practice relevant to the disease(s) of focal interest.

The hypothesis made in this case study of the impact of DSA on existing patterns of medical practice and technology use in the diagnosis and treatment of cerebrovascular disease is illustrated in figures 5-1 and *5-2*. Prior to the introduction of DSA, as figure 5-1 depicts, the physician who encountered a patient with a TIA or a stroke had several diagnostic procedural options to consider. For a number of reasons, the physician may have decided that no tests were indicated, perhaps because of coexistent medical problems that made invasive testing and surgical therapy unwarranted. In other circumstances, the physician may have moved to noninvasive testing followed by arteriography, or arteriography could have been employed as the initial test. The interplay of technologies illustrated in figure 5-1 is based on three important assumptions:

1. No surgical therapy is currently performed without arteriography.
2. Arteriography maybe the initial diagnostic test.
3. Arteriography may be the only diagnostic test.

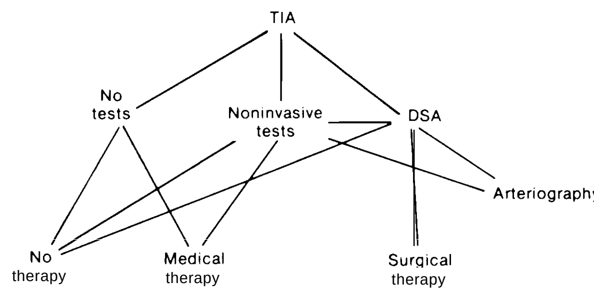
A possible fourth assumption, and one that is certainly true in many medical centers, is that radiologists and other physicians are reluctant to undertake tests with significant morbidity risks **(e.g.,** arteriography) without the opinion of a neurologist to determine that the patient's symptoms are due to TIA and therefore warrant the use of arteriography and/or surgical therapy.

Figure 5-1.— Clinical Alternatives Without DSA Available



SOURCE: Off Ice of Technology Assessment

Figure 5-2.—Clinical Alternatives With DSA Available



SOURCE: Office of Technology Assessment.

As DSA becomes increasingly available, the patterns of care associated with TIA are likely to undergo significant changes. It may be hypothesized that arteriography will less often be the initial diagnostic test, even in the case of patients with a history of definite TIA. As indicated in figure *5-2,* DSA may become the initial test of choice, or it may follow noninvasive testing of other types. On the output side, DSA maybe the final test before medical or surgical therapy, or it may lead to arteriography prior to medical/surgical intervention. The important assumptions underlying the hypothesized patterns of patient care diagramed in figure 5-2 are:

1. The sensitivity and specificity of DSA are generally much greater than for other noninvasive procedures under ordinary conditions of use.

2. The accuracy of DSA is somewhat less than arteriography, but DSA is much safer and less uncomfortable for the patient.
3. Arteriography is almost never performed (except in certain academic medical centers) without prior DSA examination, where the latter test is readily available.
4. Surgery may be undertaken without arteriography in selected cases.

Support for some of these assumptions is provided by Little and colleagues *(65):*

> In a previous study (19), . . . there was excellent correlation between the conventional angiogram and the intravenous [DSA] when the carotid bifurcation was well visualized (i.e., sensitivity, 95 percent; specificity, **99** percent; accuracy, 97 percent). When the carotid bifurcation was not well visualized by intravenous [DSA], there was a substantial chance of misinterpretation of the study results. The most common cause of misregistration was the patient's swallowing. Overall, the intravenous digital subtraction angiogram was found to accurately demonstrate the carotid bifurcations in 71 percent of the arteries evaluated. In the present study, 96 percent of the carotid bifurcations were adequately visualized.
>
> Although conventional angiography was usually recommended in patients treated surgically, intravenous [DSA] obviated the need for conventional studies in the evaluation of many patients. Some patients having extracranial and intracranial studies underwent carotid artery surgery without the need for further investigations.

The sponsors of the first outpatient ambulatory neurodiagnostic center in the State of New Jersey indicate anecdotally (45) that DSA has proven to be a significant advance in the evaluation of patients with cerebrovascular disease. According to Michael L. Gruber, M. D., a neurologist with this group:

> . . . Our experience indicates that of those patients who have surgically amenable abnormalities of the carotid bifurcations, no further studies are indicated in the majority (approximately 80 percent). In other words, the surgeon will operate on the basis of the digital subtraction angiogram. In the other 20 percent of cases, further study is required . . . because of technical problems with the DSA; because (the test revealed) total occlusion on the DSA; (in such cases the) standard procedure is to follow this with a conventional angiogram; and lastly the reluctance on the part of some surgeons to accept this new modality of investigation (45).

As a further indication of the extent to which DSA may substitute for conventional angiography as the diagnostic test establishing the need for carotid artery surgical therapy, Little and colleagues (64) summarized the experience with DSA at the Cleveland Clinic:

> DSA examinations frequently obviated the need for conventional angiography. Some patients having satisfactory extracranial and intracranial studies underwent carotid endarterectomy without further contrast studies. The number of patients undergoing carotid surgery without conventional arteriography continues to increase.

Because DSA has not yet gained widespread use as a diagnostic procedure, the data do not exist by which to accurately predict the patterns of use which will develop for the diagnosis and treatment of cerebrovascular disease. It is possible, however, to speculate on some of the ways in which DSA might be used, given current patterns of practice in disciplines such as neurology and primary care specialities. The following six assumptions are made as the basis of a cost effectiveness analysis of DSA:

1. **The technical proficiency of DSA is expected to rapidly improve as a result of the intense competition among the major imaging equipment manufacturers.**
2. **As the speed and spatial resolution of DSA studies improve and the quality of ancillary technology improves, more and more patients will have only a DSA procedure before undergoing cerebrovascular surgery.**

Detmer and colleagues (24) estimated that if no more than 5 percent of positive DSA examinations were followed by conventional arteriography for confirmation purposes, a savings of approximately $1,100 per discovered lesion would result.

3. **It is unlikely that only one DSA study will be performed per discovered lesion. It seems more likely that a minimum of two DSA ex-**

aminations (one before and one after therapy) will become the pattern of care.

This would especially be the case for all surgically treated patients, since the postoperative DSA examination would serve as a new "baseline" for the future. Among medically treated patients, it seems reasonable to assume that many will receive repeat examinations at yearly intervals to determine whether the pathology has progressed and to learn whether the stenosis of the carotid arteries has become more serious. Hence, only among patients where the DSA exam did not find a lesion can one assume that a single examination will suffice.

4. **The population of patients receiving DSA examinations in the future is likely to be much larger than the current number who receive in-hospital arteriography.**

Freedman (33), and Detmer and colleagues (24) both estimate the number of patients who will receive DSA examinations as twice the number presently having conventional arteriography. The 1977 Cooperative Study of TIA (102) reported an average of 5,4 definite TIAs per 100 acute care beds per year (the highest rate being 8.8 TIAs per 100 beds per year). Freedman (33) and Detmer (24) assumed that 95 percent of the higher prevalence estimate (or 8.5 per 100 beds) would receive arteriograms. Thus, previous studies and their assumptions suggest that as many as 17.4 DSA examinations per 100 acute care beds will be performed annually in U.S. hospitals.

Because DSA is an ambulatory care procedure, however, the "burden of illness" in the total population may be a more reasonable guide for the estimation of potential utilization, rather than the frequency of relevant diagnoses per 100 acute hospital beds. Available data (62) suggest that the incidence of TIA is 30 per 100,000 population per year with an average episodic duration of 5 years, or a prevalence of 150 per 100,000. Physicians are likely to "follow" patients with recurrent TIAs with repeated examinations, especially as the imaging quality improves.

In addition, virtually all patients with a completed stroke would likely receive a DSA examination. The incidence of stroke is *150* per 100,000 per year with an average duration of 4 years. Since a completed stroke is considered to be a relative contraindication for surgical intervention, few such patients now receive arteriography unless subsequent TIAs occur, or the treating physician finds evidence that a major stroke might subsequently occur after a minor stroke that has left relatively little intellectual and motor impairment. Since DSA is much safer than arteriography, it is assumed that many stroke patients will receive this examination. A DSA exam following a stroke may help the physician determine prognosis for family counseling, even though relatively few demonstrated lesions in stroke patients will receive surgical therapy.

If one assumes that 90 percent of new TIAs, 70 percent of new strokes, 30 percent of old TIAs, and 10 percent of old strokes receive a DSA examination annually, then 237 (27 + 105 + 45 + 60) DSA examinations for carotid artery disease per 100,000 population would seem a reasonable estimate. This figure is much larger than one based on hospital data from New Haven, Connecticut, that was estimated at 33 per 100,000 population (34).

5. **The prevalence of asymptomatic extracranial occlusive vascular disease will further increase the volume of DSA procedures performed.**

It has been estimated that in asymptomatic individuals, there is a *22* percent prevalence of arterial stenosis of the extracranial and major intracranial vasculature sufficiently severe to compromise the arterial lumen by at least 50 percent (96,97). Many of these patients have abnormal clinical signs on examination, even though no symptoms were present before the exam. These signs include bruits (murmurs) audible through a stethoscope placed adjacent to a compromised artery, diminished arterial pulsations, and an abnormally low blood pressure recorded distal to (beyond) a stenotic vessel. Many of these patients will likely receive a DSA examination, especially prior to administration of general anesthesia for a surgical procedure elsewhere in the body, because of a concern that a stroke might occur during surgery even in the absence of prior symptoms. Except under unusual circumstances (such as prior to prolonged surgery) patients with asymptomatic occlusive vascular disease do not now receive arteriograms. With the ready availability of a safe and effective diagnostic tool such as DSA, many asymptomatic patients with abnormal signs on clinical examination will likely receive a diagnostic evaluation. It appears to be a safe assumption that the indications for surgical therapy may be expanded to include asymptomatic patients with severe stenosis discovered by DSA examinations. This will result in an overall increase in the number of surgically treated lesions.

6. **The increasing availability of DSA, its technical quality and its extremely low morbidity will significantly alter the pathway through which patients with TIA are evaluated and/or referred by primary care physicians.**

Because of the risk of complication associated with conventional arteriography and the relatively large radiation exposure (20 roentgens per examination for arteriography vs. 3.6 for DSA), patients are now carefully screened by their physicians before arteriography is scheduled. This screening occurs in two ways: First, as shown in figure 5-1 above, preliminary noninvasive tests (e.g., ultrasonography) are often performed in order to reduce the likelihood of a "true negative" arteriographic examination. Most experienced clinicians prefer to screen all but the most urgent patients before performing an arteriogram. Thus, patients for whom arteriography is the first and only examination are a minority of those receiving this examination.

Second, the screening process includes a neurologist's opinion that a patient's symptoms are likely to come from extracranial occlusive vascular disease. Many primary care physicians diagnose TIA for symptoms that necrologic specialists would place in other categories. For example, dizziness is a common symptom among the elderly, especially when one first arises from a seated or lying position. Neurologists know that most dizzy patients do not suffer the types of stroke that would signal the occurrence of TIAs even if they have symptoms of dizziness and vertigo (without other symptoms and signs). Furthermore, symptoms in the extremities may represent focal seizures (localized to one part of the body), and these may be misdiagnosed as TIAs by the less experienced non-neurologist. Many patients with acute confusional states, due to a variety of toxic and metabolic causes, are also falsely labeled as having had TIAs. For these and other reasons, many radiologists will not accept patients for arteriographic examinations of the extracranial vasculature unless a neurologist has been consulted.

It maybe hypothesized that DSA may significantly alter the pathway through which patients with suspected cerebrovascular disease are managed. It is possible that both primary care physicians and radiologists may become convinced that the superior quality of DSA images and the lower morbidity risk of the procedure itself can allow some proportion of patients with suspected TIA to be managed without neurology specialty consultation. However, the American Neurological Society strongly suggests that appropriate neurological advice should be sought even in the most straightforward of cases.

QUANTITATIVE ESTIMATES OF THE COST EFFECTIVENESS OF DSA

Measuring the cost effectiveness of DSA in the diagnosis of patients with carotid artery disease is a complex task. Because several factors which influence the acquisition, use, and efficacy of DSA are variable, a *range* of costs must be incorporated into the analysis.

The data presented in the tables that follow represent the variability in cost effectiveness which can be expected in the operation of DSA under different institutional and clinical circumstances. These data are largely based on secondary information in previous studies of DSA (see principally

24,33). These studies provide important indicators of the specific cost parameters of DSA. Because their methods are limited in scope, these studies also pose certain limitations for these analyses.

Estimates of the cost effectiveness of DSA reported in this case study are based on the predicted patient charges necessary to cover the costs of operation of a DSA unit. The use of billed charges in the calculation of cost effectiveness indicators does not identify the actual flow of resources (revenues) to the production of DSA examinations, since patient or insurance payments will most likely fall below the level of billed charges. The primary concern here, however, is comparing the *relative* amount of outlays for a specific set of medical procedures—the diagnostic imaging of carotid artery disease—as a new technology (DSA) is introduced into the field of diagnostic radiology. Since data on the costs of conventional carotid arteriography are unavailable in the literature, DSA *charges* have been estimated for comparison with charges for conventional arteriography reported by Freedman *(33)* and Detmer and colleagues *(24).*

Another issue is the appropriateness of the cost effectiveness indicators employed in this analysis. It may be argued that the indicator used in prior studies, cost per lesion found, is an incomplete measure of the costs of cerebrovascular diagnosis. Because arteriograms are assumed to follow only positive DSA tests, the costs of further diagnostic evaluation following negative DSA tests are missing.

Hypothetically, the costs associated with negative DSA results may be of two kinds: 1) costs of arteriography or other testing ordered by conservative clinicians who want to confirm the negative DSA results, and 2) costs of patient disability or death due to false negative DSA tests, where the failure of DSA to show arterial disease prevented timely medical or surgical intervention. Realistically, technical improvements in DSA imaging and physician experience with the technology should reduce followup testing of negative DSA findings to insignificant levels. Indeed, it is likely that positive DSA exams will be a sufficient basis for making decisions regarding surgical intervention *(45,64,65).* Furthermore, clinical tests of DSA show that when a good (i. e., diagnostically useful) image is produced (approximately 85 percent with an experienced radiologist), the sensitivity of the procedure is close to 95 percent in the examination of the carotid arteries (19). In other words, only 5 percent of all patients with actual arterial disease will have a negative DSA finding.

It is reasonable, therefore, to assume that nearly all the costs of carotid artery imaging are incorporated into the measures of "charges per lesion found" and "charges per patient examined" as estimated in this case study. These measures are not ideal, because they do not indicate the effectiveness of DSA in improving clinical therapy or patient outcomes, but they do estimate an important unit of analysis, the cost of diagnosing carotid artery disease.

DSA charges must reflect: 1) fixed capital costs of the DSA equipment and facility; 2) semi-fixed costs for radiological personnel, equipment maintenance, administration, and utilities; 3) costs of supplies; and 4) professional fees. Total annual fixed costs are estimated by Freedman *(33)* to be from $274,000 to $448,000. Table 5-2 shows the charges which are necessary to cover the costs of DSA operation at a volume of 1,500 and 2,000 cases per year at several levels of fixed costs for a DSA facility.[1] These charges range from *$446* to *$648* per examination.

The most important determinants of the cost effectiveness of DSA, as calculated in tables 5-3 through 5-7, are charges and yield rates for DSA exams and charges for arteriograms which may be ordered to followup DSA findings. By varying the values of these three parameters, it is possible to conduct a sensitivity analysis of the cost effectiveness of DSA under various clinical and institutional patterns of operation.

Yield rates for DSA—the number of lesions identified per 100 DSA exams performed—are predicted to reach 80 percent for the examination of patients who previously would have received an arteriogram. This figure is comparable to the

[1]This case study, following Freedman (33), assumes that patient revenues will be approximately 80 percent of billed charges due to bad debts and cost-based reimbursements.

Table 5-2.—Estimated Charges for DSA Examinations

Total annual fixed costs[a]	supply Costs[a] per exam	Exams/year	Total cost/exam	Breakeven charge[b]	Professional fees[a]	Total charges/exam
$274,000	$100	1,500	$283	$353	$150	$503
		2,000	237	296		446
$318,000	100	1,500	312	390	150	540
		2,000	259	323		473
$360,000	100	1,500	340	425	150	575
		2,000	280	350		500
$404,000	100	1,500	369	462	150	612
		2,000	302	377		527
$448,000	100	1,500	399	498	150	648
		2,000	324	405		555

[a]Levels of fixed costs, supply costs, and professional fees are estimated on basis of information provided by Freedman (1982). Current supply costs are estimated in 1982 to average approximately $100 per DSA examination, allowing for a 20 percent waste and repeat study factor.
[b]Also following Freedman (1982), it is assumed that patient revenues will be approximately 60 percent of billed charges due to bad debts and cost-based reimbursements. If receipts after bad debt and acceptance of assignment (of fees by third-party payers) are expected to equal 60 percent of charges, the breakeven charge equals 1.25 times costs.

SOURCE: Office of Technology Assessment, following G. S. Freedman, "Economic Analysis of Outpatient Digital Angiography," *Applied Radio/ogy* 11(3): 29-38, 1982.

Table 5-3.—Estimates of the Cost Effectiveness of DSA (with fixed charges for arteriography)[a]

Protocol	DSA exams	Lesions found	Arteriography exams	Total charges billed[b]	Cost-effectiveness indicators: Charge per lesion found	Cost-effectiveness indicators: Charge per patient examined
1 (arteriogram only)	0	80	100	$120,000	$1,500	$1,200
II (arteriogram if DSA positive)	100	80	80	(a) 140,600	1,758	1,406
				(b) 153,500	1,919	1,535
				(c) 160,800	2,010	1,608
III (arteriogram only for 50% of positive DSAs)	100	80	40	(a) 92,600	1,158	926
				(b) 105,500	1,319	1,055
				(C) 112,800	1,410	1,128
IV (arteriogram only for 10% of positive DSAs	100	80	8	(a) 54,200	678	542
				(b) 67,100	839	671
				(c) 74,400	930	744

[a]Arteriography charge: $11200
[b]DSA charges: a) S446, b) $575, c) $648.

SOURCE: Office of Technology Assessment. Arteriography charge estimated by G. S. Freedman, "Economic Analysis of Outpatient Digital Angiography," *Applied Radiology* 11(3): 29-38, 1982

yield of positive findings from conventional arteriography. The safety and efficacy of DSA in patient diagnosis will allow or encourage a much larger population to be examined than could be done previously with arteriography, however. It is estimated in the literature that the population at risk for carotid artery diseases is two to three times larger than that which can currently be screened by arteriography **(24,33,102).** Earlier, the argument for estimating the annual volume of DSA procedures at or near *237* per **100,000** population was made. This figure is more than seven times higher than the 33 per 100,000 estimated to be receiving arteriography at the present time. For this larger group, the yield of positive DSA findings is likely to be considerably less than the current yield of arteriography or DSA.

The yield rates of DSA for this expanded population are estimated to range from 25 percent upward (24,33). Tables 5-5 through 5-7 incorporate yield ratios of 25, 50, and 80 percent in the new populations to be screened with DSA.

Arteriography charges are set at $1,200 in Freedman's (33) study of the cost effectiveness of DSA. This corresponds closely with the charge of $1,120 at the University of Wisconsin reported by Detmer and colleagues (24). Therefore, in the

Table 5-4.—Estimates of the Cost Effectiveness of DSA
(with variable charges for arteriography)[a]

Protocol	DSA exams	Lesions found	Arteriography exams	Arteriography charge	Total charges billed[b]	Cost-effectiveness indicators: Charges per lesion found	Cost-effectiveness indicators: Charges per patient examined
I (arteriogram only)	0	80	100	$1,200	**$120,000**	**$1,500**	**$1,200**
II (arteriogram if DSA positive)	100	80	80	1,232	(a) 143,160	1,790	1,432
					(b) 156,060	1,951	1,561
					(C) 163,360	2,042	1,634
III (arteriogram only for 50% of positive DSAs)	100	80	40	1,306	(a) 96,840	,211	968
					(b) 109,740	,372	,097
					(c) 117,040	,463	,170
IV (arteriogram only for 100/0 of positive DSAs)	100	80	8	1,379	(a) 55,632	695	556
					(b) 68,532	857	685
					(C) 75,832	948	758

aThe variable charges for arteriography reflect the following assumptions:

1 Patient charges are set at a level such that actual patient receipts will just offset, or break even with, the costs of patient care at the current volume of procedures If patient receipts, after bad debts and acceptance of assignment, average 60 percent of billed charges, then the estimated breakeven cost per arteriogram is $960 (0.60 x $1200 current charge)

2 The cerebrovascular studies in which DSA may effectively replace arteriography represent about one-quarter of the current volume of arteriograms.

3 Approximately 50 percent of the long-run costs of arteriographic facilities are fixed

Given these assumptions, the estimated breakeven charge per arteriogram at any new volume of arteriography is equal to:

$$(0.80)\ \text{Breakeven arteriography charge} = \frac{\left(\text{100\% current volume}\right)\left(\text{\$480 fixed cost per exam}\right) + \left(\bar{x}\text{\% new volume}\right)\left(\text{\$480 variable cost per exam}\right)}{\text{\% new volume procedures}} \quad \text{—or—}$$

$$\text{Breakeven arteriography charge}\ (1.25) = \frac{\left(\text{100\% current volume}\right)\left(\text{\$480 fixed cost per exam}\right) + \left(\bar{x}\text{\% new volume}\right)\left(\text{\$480 variable cost per exam}\right)}{\text{\% new volume procedures}}$$

Where the new volume of arteriography is equal to the current volume of arteriography minus one-quarter the percentage reduction in cerebrovascular arteriography due to DSA substitution

bDSA charges a) $446, b)$575, c) $648

SOURCE: Office of Technology Assessment

calculations in tables 5-3 and 5-5, a fixed charge of $1,200 for arteriograms is used in calculating total imaging charges per patient examined and per lesion found.

It is reasonable to assume the DSA will replace a certain percentage of arteriography. As the volume of arteriograms changes, the charges necessary to cover the fixed capacity of arteriographic facilities must also vary. Fineberg (31) notes that only 5 to 15 percent of the costs of CT scanning are variable with volume, and variable costs of DSA appear to range from *25* to 35 percent of total costs. For arteriography, high fixed costs may be lowered considerably by the combination of DSA and arteriographic facilities and personnel. Thus, tables 5-4, 5-6, and 5-7 assume that 30 percent of all costs of arteriography are fixed and calculate the measures of cost effectiveness on the basis of anticipated new (reduced) charges for arteriograms.

It should be noted that utilization of arteriography may not decrease in terms of the absolute numbers of examinations performed. The use of arteriography depends on the acceptance of DSA by radiologists and clinicians as a substitute imaging procedure. Data in table 5-7 show that if the population examined for carotid artery disease expands to four times its current volume (i.e., from 100 to *400* DSA exams), it is very likely that the demand for arteriography will rise (and its cost per exam will fall). The clinical protocols developed by Freedman (33) are used in tables 5-3 through s-7 to estimate the "charges per lesion found" and "charges per patient examined" as DSA is partially substituted for arteriography in the diagnosis of carotid artery disease. At this time

Table 5-5.—Estimates of Cost Effectiveness of DSA for Expanded Population At Risk[a] With Variable Yield Rates for Positive Findings

Protocol	DSA exams	Lesions found[b]	Arteriography exams	Total charges billed[c]	Cost-effectiveness indicators: Charges per lesion found	Cost-effectiveness indicators: Charges per patient examined
II (arteriogram if DSA positive)	200	A. 160	160	(a) $281,200	$1,758	$1,406
				(b) 307,000	1,919	1,535
				(C) 321,600	2,010	1,608
	200	B. 130	130	(a) 245,200	1,886	1,226
				(b) 271,000	2,085	1,355
				(C) 285,600	2,197	1,428
	200	c. 105	105	(a) 215,200	2,050	1,076
				(b) 241,000	2,295	1,205
				(C) 255,600	2,434	1,278
III (arteriogram only for 50% of positive DSAs)	200	A. 160	80	(a) 185,200	1,158	926
				(b) 211,000	1,319	1,055
				(C) 225,600	1,410	1,128
	200	B. 130	65	(a) 167,200	1,286	836
				(b) 193,000	1,485	965
				(C) 207,600	1,597	1,038
	200	c. 105	53	(a) 152,800	1,455	764
				(b) 178,600	1,701	893
				(C) 193,200	1,840	966
IV (arteriogram only for 10% of positive DSAs)	200	A. 160	16	(a) 108,400	678	542
				(b) 134,200	839	671
				(C) 148,800	930	744
	200	B. 130	13	(a) 104,800	806	524
				(b) 130,600	1,005	653
				(C) 145,200	1,117	726
	200	c. 105	11	(a) 102,400	975	512
				(b) 128,200	1,220	641
				(C) 142,800	1,360	714

[a]Assumes the population at risk which can be safely studied will double in size (24). This is regarded as a minimum level of additional volume Of DSA procedures Performed.
[b]DSA yield ratios:
(A) 60 percent (if volume of procedures is assumed at current level)
(B) 50 percent
(C) 25 percent (Yield ratios of those procedures beyond the current volume, e.g., 100 procedures in this example. Hence, yield ratios in (B) and (C) are calculated at 60 percent for the first 100 procedures performed and at 50 percent and 25 percent, respectively, for all procedures performed beyond the initial 100,)
[c]DSA charges: a) $446, b) $575, c) $648. Arteriography charge: $11200

SOURCE: Office of Technology Assessment.

there is no simple level of substitution that seems most likely; instead, it appears that over time, substitution of DSA for arteriography will increase, but with no predictable upper limit.

Because the patterns of clinical use of DSA are difficult to predict, it is also difficult to estimate accurately the cost effectiveness of this new technology. Certain trends are evident from the data presented in tables 5-3 through 5-7, however:

Ž As DSA substitutes for arteriography in the diagnosis of carotid artery disease, the cost effectiveness of DSA increases, and total costs of diagnostic imaging are reduced.
- As the yield of positive findings with DSA decreases due to the application of this technology to a larger population of cases, the costs per patient decline, but the cost per lesion found rises.
- As the population examined for carotid lesions increases, total costs per diagnostic imaging are virtually certain to increase regardless of how effective DSA is or how much it replaces arteriography. That is, the intro-

Table 5.6.—Estimates of the Cost Effectiveness of DSA for a Population At Risk[a] With Variable DSA Yield Rates and Variable Arteriography Charges

Protocol	DSA exams	Lesions found[b]	Arteriography exams	Arteriography charge	Total charges billed[c]	Cost-effectiveness indicators: Charges per lesion found	Cost-effectiveness indicators: Charges per patient examined
II (arteriogram only if DSA positive)	200	A. 160	160	$1,122	(a) $268,720	$1,680	$1,344
					(b) 294,520	1,840	1,473
					(C) 309,120	1,932	1,546
	200	B. 130	130	1,158	(a) 239,740	1,844	1,199
					(b) 265,540	2,043	1,328
					(C) 280,140	2,155	1,401
	200	c. 105	105	1,193	(a) 214,465	2,043	1,072
					(b) 240,265	2,288	1,201
					(C) 254,865	2,427	1,274
Ill (arteriogram only for 500/0 of positive DSAs)	200	A. 160	80	1,232	(a) 187,760	1,174	939
					(b) 213,560	1,335	1,068
					(C) 228,160	1,426	1,141
	200	B. 130	65	1,258	(a) 170,970	1,315	855
					(b) 196,770	1,514	984
					(C) 211,370	1,626	1,057
	200	C. 105	53	1,280	(a) 157,040	1,496	785
					(b) 182,840	1,741	914
					(c) 197,440	1,880	987
IV (arteriogram only for 100/0 of positive DSAs)	200	A. 160	16	1,359	(a) 110,944	693	555
					(b) 136,744	855	684
					(c) 151,344	946	757
	200	B. 130	13	1,367	(a) 106,971	823	535
					(b) 132,771	1,021	664
					(c) 147,371	1,134	737
	200	c. 105	11	1,372	(a) 104,292	993	521
					(b) 130,092	1,239	650
					(C) 144,692	1,378	723

aAssumes the population at risk which can be safely studied will double in size (24) This is regarded as a minimum level of additional volume of DSA procedures performed

bDSA yield ratios

(A) 80 percent (if volume of procedures is assumed at current level)

(B) 50 percent

(C) 25 percent (Yield ratios of those procedures beyond the current volume, e g., 100 procedures in this example Hence, yield ratios in (B) and (C) are calculated at 80 percent for the first 1 00 procedures performed and at 50 percent and 25 percent. respectively, for all Procedures Performed beyond the initial 100)

cDSA charges a) $446 b) $575, c) $648

SOURCE Off Ice of Technology Assessment

duction of DSA is likely to represent an addition to the costs of health care in the treatment of carotid artery diseases.

- The variations in cost effectiveness and total costs of DSA due to changes in costs (and charges) of DSA and arteriographic facilities are often small relative to the variations caused by the patterns of DSA utilization.

Table 5-7.—Estimates of the Cost Effectiveness of DSA for a Population At Risk Expanded Four-Fold With Variable Yield Rates for Baseline Findings (with fixed charges for arteriography)[a]

Protocol	DSA exams	Lesions found[b]	Arteriography exams	Arteriography charge	Total charges billed[c]	Cost-effectiveness indicators: Charges per lesion found	Cost-effectiveness indicators: Charges per patient examined
II (arteriogram only if DSA is positive)	700	A. 560	560	$1,200	(a) $ 984,200	$1,758	$1,406
					(b) 1,074,500	1,919	1,535
					(C) 1,125,600	2,010	1,608
	700	B. 380	380	1,200	(a) 768,200	2,022	1,097
					(b) 858,500	2,259	1,226
					(c) 909,600	2,394	1,299
	700	C. 230	230	1,200	(a) 588,200	2,557	840
					(b) 678,500	2,950	969
					(c) 729,600	3,172	1,042
III (arteriogram only for 50% of positive DSAs)	700	A. 560	280	1,200	(a) 648,200	1,158	926
					(b) 738,500	1,319	1,055
					(c) 789,600	1,410	1,128
	700	B. 380	190	1,200	(a) 540,200	1,422	772
					(b) 630,500	1,659	901
					(c) 681,600	1,794	974
	700	C. 230	115	1,200	(a) 450,200	1,957	643
					(b) 540,500	2,350	772
					(c) 591,600	2,572	845
IV (arteriogram only for 10% of positive DSAs)	700	A. 560	56	1,200	(a) 379,400	678	542
					(b) 469,700	839	671
					(c) 520,800	930	744
	700	B. 380	38	1,200	(a) 357,800	942	511
					(b) 448,100	1,179	640
					(c) 499,200	1,314	713
	700	C. 230	23	1,200	(a) 339,800	1,477	485
					(b) 430,100	1,870	614
					(c) 481.200	2.092	687

[a]The fixed charges for arteriography correspond to current charges for the procedure in 1982-83 (33), assuming that arteriographic facilities are Operating at full Capacity or efficiency, The population examined with DSA, then referred for arteriography, will expand by a factor of 2 to 6 This will require additional arteriographic facilities which would also presumably operate at full capacity or efficiency in the long run

[b]DSA yield ratios:

(A) 80 percent (if volume of procedures is assumed at current level)
(B) 50 percent
(C) 25 percent (Yield ratios of those procedures beyond the current volume, e.g , 100 procedures in this example. Hence, yield ratios in (B) and (C) are calculated at 60 percent for the first 100 procedures performed and at 50 percent and 25 percent, respectively, for all procedures performed beyond the initial 100)

[c]DSA charges a) $446, b) $575, c) $648

SOURCE Off Ice of Technology Assessment