Complications of peripheral arteriography: A new system to identify patients at increased risk

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Purpose: **The most quoted literature on arteriographic complications is based on self-reports collected during the mid 1970s. We sought to determine whether those results remain valid despite changes in arteriographic practice and whether patient subgroups at increased risk could be identified.**

Methods: **Five hundred forty-nine consecutive patients were examined after arteriography and twice over 72 hours. Patients were telephoned at least 2 weeks later to identify delayed complications. The sample was divided into two groups to allow independent validation of suspected prognostic factors.**

Results: **The rate of major complications was 2.9% (16/549), but varied from 0.7% to 9.1% among three strata of relative risk. Rates were highest in patients studied for suspected aortic dissection, mesenteric ischemia, gastrointestinal bleeding, or symptomatic carotid artery stenosis and lowest in patients with trauma or aneurysmal disease. Patients studied for claudication or limb-threatening ischemia had intermediate risk (2.0%). Within these strata, congestive heart failure and furosemide use were the only variables independently associated with a significantly increased complication rate.**

Conclusions: **Previous reports have overestimated the risk of arteriography for trauma or aneurysm but substantially underestimate the risk for patients with other common conditions. Such stratified complication rates are essential to understand relative costs and benefits of arteriography and other vascular imaging modalities in specific clinical situations. (J VASC SURG 1995;22:787-94.)**

Peripheral arteriography plays a pivotal role in the diagnosis and management of a wide variety of disorders, including extremity and mesenteric ischemia, gastrointestinal bleeding, hemoptysis, aortic dissection, arterial injuries, and carotid artery disease. Despite this broad application, arteriography is often regarded as expensive, hazardous, and arduous. Although the development of noninvasive vascular imaging tests has been driven by a desire to avoid the dangers of conventional arteriography,[1,2] the causes and incidence of these complications have seldom been investigated. No prospective studies describing the expected complication rate of peripheral arteriography have been published during the past decade, despite many procedural improvements, including the selective use of low osmolar contrast media, a reduction in the caliber of angiographic catheters, intraarterial digital subtraction arteriography, and the introduction of outpatient arteriography.

The usually quoted rates of complications for arteriography come from two relatively old reports. In 1978 Sigstedt and Lunderquist[3] prospectively studied 1217 adult patients, for whom physicians completed a standardized form after the examination, and visited the following day. Despite many details about an array of complications, rates were not specifically cited for overall complications or for those that had an impact on patient care or outcomes. In 1981 Hessel et al.[4] mailed questionnaires to radiologists at 2066 hospitals and calculated an overall major

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complication rate of 1.9% from the 25% response rate of 514 radiologists.

Despite wide acceptance of these estimates,[5-7] most experienced angiographers have noted that certain types of procedures, such as arch aortography for patients with trauma, are associated with a relatively low complication rate, whereas others, like selective carotid arteriography, seem to have more frequent adverse events. Differing complication rates have never been documented but would be important for current patient care and for the assessment of emerging noninvasive vascular imaging modalities. Because competing imaging technologies such as magnetic resonance angiography and color-flow ultrasonography must be appraised with an objective understanding of the costs of the tests they are intended to replace, the absence of data on complication rates might inappropriately accelerate or impede the acceptance of newer modalities.

Our goal in this research was to measure, in a rigorous, prospective fashion, the complication rate associated with peripheral arteriography in contemporary practice. We sought to determine whether certain arteriographic procedures were consistently either more hazardous or safer than a single, overall risk estimate might suggest. Similarly we hoped to learn whether analysis of preprocedural patient characteristics might alone identify subgroups of patients at increased risk of arteriographic complications. The hope was that patients and their physicians could be given a more accurate assessment of the risks associated with a selected procedure.

PATIENTS AND METHODS

Patients. During a 6-month interval, 556 patients were referred for 607 non-coronary, nonintracerebral arteriograms at the Massachusetts General Hospital; all patients were enrolled in this prospective cohort. When informed consent was obtained for the procedure, the physician used a standardized data collection form to record information about demographic characteristics, medical history, prescription medications, allergies, and habits such as smoking and alcohol consumption.

In 47 patients who received more than one arteriogram, only the first examination is included in this analysis to avoid exaggeration of the impact of particular patient characteristics on the complication rate. Five patients receiving urokinase therapy were excluded from further analysis because thrombolysis procedures, which involve prolonged arterial catheterization during the administration of clot-dissolving drugs, have a completely different risk-benefit ratio than diagnostic arteriography.

Angiographic technique and periprocedural care. The attending angiographer was responsible for selection of puncture site, catheter sizes, radiographic contrast agents, and volume of contrast administered. Information about each of these variables was recorded for every patient. According to department guidelines, low osmolar ("non-ionic") contrast agents were used in elderly patients or those with previous contrast allergy or congestive heart failure. At the conclusion of every procedure, the puncture site was compressed for at least 15 minutes, and hemostasis was achieved by use of manual compression alone. All inpatients received overnight hydration before scheduled procedures and outpatients were given specific instructions for oral hydration. All patients were given intravenous fluids for at least 6 hours after completion of the arteriogram, and it was our policy to administer intravenous mannitol (12.5 to 25 gm) and furosemide (20 to 40 mg) to all patients with a preprocedure creatinine of 1.5 mg/dl or greater.

Follow-up methods. Presence and details of any complication before departure from the radiology department were recorded, and all patients were interviewed and examined twice during a 72-hour period after the angiographic procedure. For all available patients, the second examination occurred between 3 and 12 hours after the procedure, and another visit was made on the next working day between 36 and 72 hours after the procedure. Discharged patients, or those undergoing outpatient procedures were interviewed by telephone. Two physical examinations were completed for 540 subjects (98%), and 441 patients (80%) were available for all three visits. Patients with identified complications were regularly monitored to determine both severity and clinical significance. All inpatients received daily blood urea nitrogen and serum creatinine determinations for the next two mornings after angiographic study.

For all patients, long-term follow-up information was sought between 14 days and 3 months after the angiographic procedure. Patients still in hospital were visited, interviewed, and examined, and discharged patients were interviewed by telephone. Direct contact was accomplished with 407 patients (74%), but information was sometimes obtained from immediate family or caretakers (n = 105, 19%). Further information on patients who could not be examined personally or who could not be contacted by telephone was obtained by review of hospital, outpatient, and private office charts (n = 37, 7%). Immediate and long-term follow-up information of this kind was obtained with these

methods for 549 of 551 eligible subjects (99.6%); the other two patients left the Boston area and were unavailable for interview or physical examination.

Definitions of complications. A complication was classified as major if it led to operative or transcatheter repair, permanent morbidity, a blood transfusion, or delay of an urgent surgical procedure. Minor complications were defined as immediately correctable events that required additional, unexpected therapy; for example, puncture site bleeding rectified with additional compression. Nonsignificant complications were adverse occurrences that were clearly related to the angiographic procedure, such as a groin ecchymosis or transient nausea, but that required no additional intervention and did not alter the patient's hospital course.

The evaluation of contrast-induced renal insufficiency required special consideration. Because patients discharged from hospital or who underwent outpatient arteriography were not available for follow-up tests of kidney function, alterations in blood urea nitrogen and creatinine alone could not be used to define renal complications without biasing the results in favor of symptom-free patients who missed follow-up testing. Among patients undergoing the same type of arteriographic study, those discharged home and unavailable for follow-up blood tests would be assumed to have fewer complications, even if their clinical courses were in fact identical to those patients who remained in hospital (detection bias[8]), simply because as a group they would have fewer abnormal blood test results. For this reason, only renal insufficiency with clinical manifestations, such as oliguria or fluid overload, was objectively identified as a complication.

Types of complications. Arterial dissections, thromboses, groin hematomas, and puncture site bleeding were considered types of vascular injuries. Patients who had acute onset of urticaria, hypotension, or laryngeal edema after administration of iodinated radiographic contrast were classified as having "contrast allergies." Less commonly observed complications, including periprocedural angina pectoris, neurologic injuries (e.g., numbness in distribution of the lateral femoral cutaneous nerve), and vasovagal episodes were grouped together in an "other complications" category. Each patient therefore was coded as having had (1) no complication, (2) a vascular injury, (3) contrast allergy, (4) contrast-induced kidney failure, or (5) other complication.

Statistical methods. In accordance with the customary procedure for validating predictive systems,[9] the 549-member cohort was randomly divided into a "training" set ($n = 274$) and a separate "testing" set ($n = 275$). The two groups were similar in age, sex, types of procedures performed, and overall complication rate (Table I). For categorical partitions age was classified in decades as less than 30 years, 30 to 39, 40 to 49, 50 to 59, 60 to 69, 70 to 79, and 80 years or older.

The incidence of clinically significant complications observed in the training set is described in Table II. On the basis of these observations, arteriographic examinations with similar complication rates in the training set were organized into three ordinal groups, designated as type 1 (lowest risk), type 2 (intermediate risk), and type 3 (highest observed complication rate). The ascending gradient in complication rates for the three qualitatively ordered groups was statistically significant according to both the chi-squared test for linear trend and its modification proposed by Bartholomew.[10] The validity of this classification was confirmed by similar and statistically significant results in the independent testing set.

In the next analytic step, to identify features of the training sample that might have predisposed to angiographic complications, all demographic and clinical variables were checked with contingency table analyses. Two variables—history of congestive heart failure (CHF) and current use of furosemide—were significantly associated with complications but identified nearly identical populations. The two variables were therefore consolidated into a single variable ("CHF or furosemide use") that was considered positive if either factor was present.

Individual baseline state features significantly associated with either major or minor complications ($p < 0.10$, Fisher's exact test) were entered into a logistic regression model to determine which characteristics, when examined in the multivariable context, maintained their impact on the complication rate. Diabetes mellitus, angiographic catheter caliber, type of contrast administered, contrast volume, and grams of iodine received were not associated with complications in the training and testing sets but are logical risk factors for arteriographic complications[11,12] and were therefore included in the list of candidate covariates receiving the logistic regression analysis. The Charlson measure of comorbidity,[13] which had been calculated from data collected about each patient, was not associated with an increased risk of angiographic complications and was not retained for subsequent analyses. Separate logistic regression analyses were performed on the entire cohort by use of a forward stepwise approach, with both clinically significant complications (major and minor), and

Table I. Baseline patient characteristics (*no. [%] of patients*)

	Training sample (n = 274)	*Testing sample (n = 275)*	*Total (n = 549)*
Age in years (mean ± SD)	59 ± 17	59 ± 18	59 ± 18
Women	105 (38)	88 (32)	193 (35)
Patient condition			
Good	208 (74)	212 (77)	420 (75)
Fair	56 (20)	49 (18)	105 (19)
Critical	16 (5)	16 (5)	32 (5)
Comorbidity index (mean ± SD)	1.7 ± 1.2	1.7 ± 1.3	1.7 ± 1.3
Arteriographic studies*			
Type 1	71 (26)	76 (28)	147 (27)
Type 2	177 (65)	170 (62)	347 (63)
Type 3	26 (10)	29 (11)	55 (10)
History			
Allergies	72 (26)	55 (20)	127 (23)
Contrast allergy	5 (2)	6 (2)	11 (2)
Congestive heart failure*	18 (7)	16 (6)	34 (6)
Diabetes	52 (19)	31 (11)	83 (15)
Hypertension	117 (43)	107 (39)	224 (41)
Coronary artery disease	66 (24)	66 (24)	132 (24)
Stroke	11 (4)	8 (3)	19 (4)
Chronic kidney failure	10 (4)	10 (4)	20 (4)
Medications			
Beta-blockers	47 (17)	58 (21)	105 (19)
Calcium channel blockers*	43 (16)	52 (19)	95 (17)
ACE Inhibitors	26 (10)	32 (12)	58 (11)
Nitrates	37 (14)	35 (13)	72 (13)
Digoxin	28 (10)	34 (12)	62 (11)
Furosemide*	27 (10)	24 (9)	51 (9)
Warfarin	15 (6)	22 (8)	37 (7)
Thiazide Diuretics	46 (17)	46 (17)	92 (17)
Antiplatelet drugs	64 (23)	46 (17)	110 (20)
H_2-receptor antagonists	21 (8)	31 (11)	52 (10)
Insulin	17 (6)	16 (6)	33 (6)
Oral hypoglycemics	21 (8)	10 (4)	31 (6)
Site of catheter introduction			
Retrograde femoral artery	263 (96)	264 (96)	527 (96)
Other	11 (4)	11 (4)	22 (4)

*Variables with significant bivariate association with complications ($p < 0.10$) in both training and testing samples.

with major complications alone as outcome measures. The Statistical Analysis System software (SAS Institute, Inc., Cary, N.C.) was used for all statistical analyses.

RESULTS

Rates of complications. There were 16 major and 35 minor complications, for major and total complication rates of 2.9% and 9.3%, respectively (Table III). The major complications included four vascular injuries (two severe hematomas and two femoral artery thromboses), two severe contrast reactions, eight cases of severe contrast-induced renal insufficiency, and transient ischemic attacks in two patients (Table IV). The 35 minor complications included 15 vascular injuries (5 hematomas, 4 vessel thromboses that did not require intervention, 5 bleeding episodes, 1 case of peripheral cholesterol embolization), 2 lesser contrast reactions that required therapy, 4 cases of mild contrast-induced renal insufficiency, 6 transient cardiovascular events (including angina, CHF, and vasovagal episodes), 1 case of transient mental status changes after an arm arteriogram, and 7 miscellaneous adverse outcomes (primarily persistent pain in the distribution of the lateral femoral cutaneous nerve).

This series included three pelvic embolizations for traumatic bleeding, five tumor embolizations, and four pitressin infusions to control gastrointestinal bleeding. There were also 10 common or external iliac artery and two superficial femoral artery angioplasties. Because there were no major complications during these 24 cases, and because the minor complication rates of these subjects (three of 24) did not differ significantly from other patients receiving similar types of arteriography, these interventional procedures were retained in the sample for all analyses.

Gradient in complications. As shown in Table III a significant gradient in the complication rate was observed among types of arteriographic studies. In the training set, major complications occurred in none of 71 type 1 studies, but in 4 of

Table II. Arteriographic studies grouped according to incidence of clinically significant complications observed in training set (no. [%] of patients)

		Complication severity	
	n	*Major*	*Major and minor*
Type 1 arteriography for arterial injury, aneurysm, or anomaly			
Trauma	26	0 (0%)	0 (0%)
Preoperative anatomy for aneurysmal disease	28	0 (0%)	1 (4%)
Preoperative anatomy for other indications	17	0 (0%)	0 (0%)
Type 2 arteriography for arterial occlusion or encasement			
Arteriography prior to cancer surgery	38	0 (0%)	4 (11%)
Suspected renal artery stenosis	22	0 (0%)	3 (14%)
Claudication	55	2 (4%)	4 (7%)
Limb-threatening ischemia	46	2 (4%)	3 (7%)
Asymptomatic carotid bruit	16	0 (0%)	3 (19%)
Type 3 arteriography in patients at risk of death or stroke			
Symptomatic carotid bruit	14	1 (7%)	4 (29%)
Gastrointestinal bleeding or mesenteric ischemia	8	0 (0%)	3 (33%)
Suspected aortic dissection	4	1 (25%)	1 (25%)

177 (2.3%) type 2 and 2 of 26 (7.7%) type 3 examinations. The trend of the gradient in these proportions was significant (chi-squared, $p < 0.05$). The same trend was noted and statistically confirmed in the testing set where the rates of major complication were 1.3% (1 of 76) among type 1 studies, 3.5% (6 of 170) among type 2, and 10.3% (3 of 29) among type 3 studies.

For the combined rate of major and minor (that is, clinically significant) complications, the training and testing samples showed a less impressive but still statistically significant trend. In the training set, the combined rate of complications was 1.4% (1 of 71) among the type 1 studies, 9.6% (17 of 177) in type 2, and 30.8% (8 of 26) in type 3 examinations. In the testing set, the combined rates were 1.3% (1 of 76) in type 1 studies, 11.8% (20/170) in type 2, and 13.7% (4/29) in type 3 studies. The gradient in the proportions observed between groups was also significant (chi-squared, $p < 0.05$).

Severity of complications. All of the vascular injuries that required surgical repair or transfusion occurred among patients undergoing arteriography for indications relating to peripheral atherosclerosis (type 2). Patients referred for type 3 studies were most likely to have other types of complications, including contrast-induced kidney failure (Table IV). Patients who had axillary or antegrade punctures were no more likely to have complications than were others who underwent type 2 studies (0 of 22 vs 10 of 325).

Impact of CHF or furosemide use. A separate analysis (Table V) indicates that the composite variable of "CHF or furosemide use" had a separate effect on the complication rate for each type of arteriographic study. Patients with a history of CHF or current furosemide use had essentially the same complication rate as patients without those characteristics in the next higher-risk group of studies. For example, patients with CHF or furosemide use who underwent type 2 arteriography had major and total complication rates of 6% and 17%, compared with 5% and 16% in patients without those characteristics undergoing type 3 arteriography.

Multivariable analysis. The results of the stepwise logistic regression are presented in Table VI. The type of arteriography and the composite "CHF or furosemide use" measure were the only variables that met the 0.05 significance level for entry into the model, with either major complications or both major and minor complications as the outcome or "dependent" variables. These findings confirm the results obtained by categorical partitioning and suggest that when other factors significantly associated with adverse events in the bivariate analysis are adjusted for, movement between groups of arteriographic studies, such as from type 1 to type 2, more than triples the risk of a major complication. Similarly, the presence of a history of CHF or current use of furosemide was associated with a fourfold increase in the risk of a major complication.

DISCUSSION

The complications of peripheral arteriography do not seem to occur in purely random fashion. In the three groups of arteriographic studies with significantly different complication rates, the indications for the study remained significant predictors of complications, regardless of the impact of baseline characteristics such as medical history or medications. Like Moore et al.,[14] we found that increasing age, a history of contrast allergy, diabetes mellitus, or chronic kidney failure were not associated with an independent increase in risk of arteriographic complications.

Table III. Rates of clinically significant complications*

		Complication severity					
		Major†			*Major and minor‡*		
	n	*No.*	*(%)*	*(95% CI)*	*No.*	*(%)*	*(95% CI)*
Training sample							
Type 1	71	0	(0.0)	(0-5.0)	1	(1.4)	(0.0-7.5)
Type 2	177	4	(2.3)	(0.6-5.7)	17	(9.6)	(5.7-14.9)
Type 3	26	2	(7.7)	(0.9-24.8)	8	(30.8)	(14.3-51.5)
All	274	6	(2.2)	(0.8-4.7)	26	(9.5)	(6.3-13.6)
Testing sample							
Type 1	76	1	(1.3)	(0.0-7.1)	1	(1.3)	(0.0-7.1)
Type 2	170	6	(3.5)	(1.3-7.5)	20	(11.8)	(7.3-17.6)
Type 3	29	3	(10.3)	(2.2-27.1)	4	(13.8)	(3.9-31.4)
All	275	10	(3.6)	(1.8-6.6)	25	(9.1)	(6.0-13.1)
Entire cohort							
Type 1	147	1	(0.7)	(0.0-3.7)	2	(1.4)	(0.2-4.8)
Type 2	347	10	(2.9)	(1.4-5.2)	37	(10.7)	(7.6-11.4)
Type 3	55	5	(9.1)	(3.0-19.9)	12	(21.8)	(11.8-34.9)
All	549	16	(2.9)	(1.7-4.7)	51	(9.3)	(7.0-12.0)

CI, Confidence interval.
*Types of arteriography are defined in Table II.
†$p < 0.05$, Bartholomew's χ^2.
‡$p < 0.005$, Bartholomew's χ^2.

Table IV. Nature of clinically significant complications according to type of arteriographic study*

		No. (%) of patients			
	n	*Vascular injury*	*Contrast allergy*	*Acute kidney failure*	*Other*
Major complications					
Type 1	147	0 (0)	1 (1)	0 (0)	0 (0)
Type 2	347	4 (1)	0 (0)	6 (2)	0 (0)
Type 3	55	0 (0)	1 (2)	2 (4)	2 (4)
Total	549	4 (1)	2 (0)	8 (1)	2 (0)
All clinically significant complications					
Type 1	147	1 (1)	1 (1)	0 (0)	0 (0)
Type 2	347	17 (5)	2 (1)	10 (3)	8 (2)
Type 3	55	1 (2)	1 (2)	2 (4)	8 (15)
Total	549	19 (4)	4 (1)	12 (2)	16 (3)

*Types of arteriography are defined in Table II. Vascular injuries included hematomas, dissections and pseudoaneurysms. Other category includes cardiovascular (angina, vasovagal) and neurologic events.

With a simple classification system based only on the type of arteriogram and the presence or absence of CHF, we distinguished groups of patients for whom the extremes of risk of a major complication differed by more than 30-fold.

The total rate of major complications observed in this study (2.9%) is relatively similar to the 1.9% reported by Hessel et al.,[4] but our results suggest that meaningful comparisons between published series may be difficult or impossible without knowledge of the types of patients and procedures included. For example, a predominance of type 1 procedures might lower the overall ("mean") complication rate in a report without affecting the actual morbidity rate within subgroups.

Previous studies of peripheral arteriographic complications and many fundamental tenets of the practice of peripheral arteriography may be mistakenly based on the assumption that all arteriograms have the same risk. For example, Hessel et al.[4] reported that the complication rate for catheter placement via the axillary artery was almost twice that observed after transfemoral artery studies (3.3% vs 1.7%). Because axillary artery puncture is almost exclusively used in patients with pulseless lower extremities undergoing type 2 or 3 examinations,[15] our results suggest that the maneuver can only be meaningfully compared with femoral artery puncture in patients undergoing similar arteriographic studies. In "high risk" procedures, reputed to be more

Table V. Cross-stratification of complication data according to presence of CHF or furosemide use at baseline*

	No. (%) of patients					
	Training sample CHF or furosemide use present		*Testing sample CHF or furosemide use present*		*Entire cohort CHF or furosemide use present*	
	No	*Yes*	*No*	*Yes*	*No*	*Yes*
Major complications						
Type 1	0/66 (0)	0/5 (0)	1/69 (1)	0/7 (0)	1/135 (1)	0/12 (0)
Type 2	2/137 (2)	2/40 (5)	3/131 (2)	3/39 (8)	5/268 (2)	5/79 (6)
Type 3	1/21 (5)	1/5 (20)	1/22 (5)	2/7 (29)	2/43 (5)	3/12 (25)
Total	3/224 (1)	3/50 (6)	5/222 (2)	5/53 (9)	8/446 (2)	8/103 (8)
All clinically significant complications						
Type 1	0/66 (0)	1/5 (20)1/69 (1)	0/7 (0)	1/135 (1)	1/12 (8)	
Type 2	12/137 (9)	5/40 (13)	12/131 (9)	8/39 (21)	24/268 (9)	13/79 (17)
Type 3	5/21 (24)	3/5 (60)	2/22 (9)	2/7 (29)	7/43 (16)	5/12 (42)
Total	17/224 (8)	9/50 (18)	15/222 (7)	10/53 (19)	32/446 (7)	19/103 (18)

*Types of arteriography are defined in Table II.

Table VI. Results of stepwise logistic regression

Outcome	*Variables selected for inclusion*	*Regression coefficient (β)*	*SE*	*OR (95% CI)*
Major complications	Study	1.24	0.47	3.5 (1.4-8.7)
	CHF or furosemide use	1.39	0.52	4.0 (1.5-11.0)
All significant complications	Study	1.20	0.28	3.3 (1.9-5.7)
	CHF or furosemide use	0.94	0.32	2.6 (1.4-4.8)

SE, Standard error of regression coefficient (β); *OR*, odds ratio (calculated as e^{β}); *CI*, confidence interval.

hazardous than transfemoral arteriography,[4,16] our results for axillary artery punctures and "antegrade" femoral artery punctures (where the catheter is directed from the groin toward the foot rather than the head), showed a complication rate (0 of 22) that did not differ significantly from other type 2 studies (10 of 325). Thus the high-risk procedures, although possibly associated with unique or more severe risks as a result of particular anatomic considerations, may be no more hazardous than femoral arteriography in similar patients.

Limitations and strengths. Preprocedural information alone predicts only a portion of the observed adverse events and intraprocedural factors presumably also affect patient outcomes.[17] Although catheter caliber[18] and volume of contrast injected[14] may have little influence on complications, certain types of arteriography carry unique risks. For example, minute thrombi arising from arteriographic catheters[19,20] are almost certain to remain silent in most parts of the body but may have catastrophic effects when injected into the carotid arteries.

Despite the relatively low number of complications observed in this cohort, we were able to confirm the statistical validity of our prognostic system in two independent samples. In addition to analyzing the types of arteriography, other strengths of this study are its prospective design and almost universal follow-up (99.6%). Most other studies have relied on chart review[17] or self-administered questionnaires,[4] which are less likely to identify complications than direct examination and interviews with patients. Unlike other authors, we also measured the occurrence of "minor" complications, which by definition do not require surgery or alter the clinical course but may be very distressing to patients.

Implications. The observation that some groups of patients are at increased risk is significant for two reasons. By understanding the hazards to which patients are subjected, referring physicians and angiographers can make better clinical decisions and can provide patients and their families with the facts needed to give a truly informed consent. Information of this type may also help define which patients or arteriographic studies are most suitable for outpatient procedures.

Although the results reported here may seem alarming, the complication rates must be interpreted in context. Many patients in the highest risk category, that is, patients with CHF undergoing type 3 studies,

who exhibited major and combined complication rates of 25% and 42%, respectively, faced short-term mortality rates approaching 100% if conditions such as mesenteric ischemia or aortic dissection were not diagnosed and treated promptly. For each patient and situation, physicians must therefore consider if the increment of information gained from the arteriogram warrants the risk.

Finally, the assessment of new technologies depends on a complete understanding of existing methods and current practice. The scientific evaluation of new "noninvasive" vascular imaging tests, for example, demands a careful synthesis of their information content or diagnostic yield (benefit) and their costs (financial and morbid) relative to arteriography. Consequently, the threshold for accepting a new technology must be adjusted according to the type of arteriography that it is intended to replace. It is easier to propose replacing type 3 studies with an alternate test, even if it offers slightly less accurate diagnostic information than type 1 examinations.

We believe that these findings substantiate Fuchs and Garber's[21] proposal that accepted technologies be reassessed intermittently. Arteriography has been in common use for several decades, but the causes and distribution of arteriographic complications are still incompletely described, and much remains to be learned about this still-indispensable procedure. Although arteriographic methods and noninvasive vascular imaging modalities continue to evolve, recognition of differential complication rates is essential to ensure that these new procedures are studied and compared in similar groups of patients. After our results have been validated in other settings, physicians can better understand the balance of benefit and risk in individual cases and can modify the causes of arteriographic complications or use alternative diagnostic tests to improve the safety of patient care.

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