UvA-DARE (Digital Academic Repository)

Interobserver variability of pulmonary angiography in patients with non-diagnostic lung scan results: conventional versus digital subtraction arteriography

van Beek, E.J.R.; Bakker, A.J.; Reekers, J.A.

DOI

[10.1148/radiology.198.3.8628860](https://doi.org/10.1148/radiology.198.3.8628860)

Publication date

1996

Published in

Radiology

[Link to publication](#)

Citation for published version (APA):

van Beek, E. J. R., Bakker, A. J., & Reekers, J. A. (1996). Interobserver variability of pulmonary angiography in patients with non-diagnostic lung scan results: conventional versus digital subtraction arteriography. *Radiology*, 198, 721-724.
<https://doi.org/10.1148/radiology.198.3.8628860>

General rights

It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations

If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: <https://uba.uva.nl/en/contact>, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.

UvA-DARE is a service provided by the library of the University of Amsterdam (<https://dare.uva.nl>)

Pulmonary Embolism: Interobserver Agreement in the Interpretation of Conventional Angiographic and DSA Images in Patients with Nondiagnostic Lung Scan Results¹

PURPOSE: To assess interobserver agreement in the interpretation of digital subtraction angiographic (DSA) images and conventional angiograms in patients with nondiagnostic lung scans.

MATERIALS AND METHODS: One hundred thirty of 397 consecutive patients (65 men, 65 women; mean age, 57 years; age range, 18–92 years) in this prospective cohort study underwent angiography. Conventional, selective series were obtained between 1991 and 1992 in 45 patients, and intraarterial DSA series were obtained between 1992 and 1994 in 85 patients. All angiograms were read immediately by the attending radiologist, independently by two radiologists after 6 months, and later by means of consensus of the two radiologists.

RESULTS: Results of the two methods were comparable. Interobserver disagreement occurred in 20%–36% ($n = 9$ –16) of patients with conventional images and 4%–11% ($n = 3$ –9) of patients with DSA images. Initial diagnoses were changed after the images were reviewed by means of consensus in 20% and 12% of patients with conventional and DSA series, respectively. In 70% of these patients, initial findings were false-positive; in 25%, inconclusive; and in 5%, false-negative.

CONCLUSION: Interobserver agreement is better with selective, intraarterial DSA than with conventional techniques.

Index terms: Digital subtraction angiography, comparative studies, 944.1222, 944.77 • Embolism, pulmonary, 60.72, 944.1222, 944.77 • Pulmonary angiography, 944.1222, 944.77 • Pulmonary arteries, stenosis or obstruction, 60.72, 944.1222, 944.1223, 944.77

Radiology 1996; 198:721–724

A diagnosis of pulmonary embolism is contemplated in approximately two to three patients per 1,000 individuals in the Western world every year (1,2). Many diagnostic strategies may be used, but lung scintigraphy is generally regarded as the screening test of choice (3–8). A normal perfusion scan rules out the presence of clinically relevant emboli, and anticoagulation therapy may be safely withheld (9–11). On the other hand, a high-probability lung scan (one that shows one or more segmental [or larger] defects with locally normal ventilation) has a degree of certainty of more than 90% for the presence of emboli, and long-term anticoagulation therapy is warranted in these patients (3,4,12–15). However, almost half of all patients who undergo lung scintigraphy will have neither a normal nor a high-probability result (3,4,8,16).

Pulmonary angiography is generally regarded as the standard of reference in the detection of pulmonary embolism (5–8). A diagnosis of pulmonary embolism can be excluded by using this diagnostic modality, and anticoagulants may be safely withheld in symptomatic patients with normal angiograms (17). Because of the invasive nature of this diagnostic technique and its related complications (18–21), pulmonary angiography is reserved for use in those patients in whom less invasive tests have been nondiagnostic (5–8).

The reproducibility of angiographic results has already been assessed, and interobserver agreement was shown to be 81% and 86% in two studies (21,22). However, in these studies pulmonary angiography was used in all patients with clinically suspected pul-

monary embolism. Hence, the consistency of findings of pulmonary angiography in patients with nondiagnostic lung scans has not been properly assessed. Furthermore, developments in conventional angiographic technique have led to the availability of digital subtraction angiography (DSA). This method reduces the interference caused by the overlapping of anatomic structures, such as the airways, interstitial structures, and venous vessels of the lungs.

This study was performed to evaluate the interobserver variability of selective pulmonary angiographic findings in patients with clinically suspected pulmonary embolism and nondiagnostic scintigraphic results. The influence of the introduction of DSA also was assessed.

MATERIALS AND METHODS

Patients

Between April 1991 and April 1994, 130 of 397 consecutive patients (65 male, 65 female; mean age, 57 years; age range, 18–92 years) with clinically suspected pulmonary embolism were referred for pulmonary angiography and were enrolled in the study. The patients had previously undergone lung scintigraphy, but the findings had been nondiagnostic. Informed consent was obtained from all patients, and approval was obtained from the institutional review board of the Academic Medical Center before the study was begun.

All patients were followed up for 6 months. Follow-up examinations consisted of an outpatient visit at 3 months and a telephone interview at 6 months. Special attention was given to the detection of new signs and symptoms suggestive of venous thromboembolism and to the detection of possible signs of bleeding complications in patients who received oral anticoagulants. In patients with new

¹ From the Department of Radiology, Academic Medical Center, Meibergdreef 9, 1105 AZ, Amsterdam, the Netherlands. Received May 16, 1995; revision requested July 6; final revision received September 25; accepted October 11. Address reprint requests to E.J.R.v.B.

© RSNA, 1996

Abbreviation: DSA = digital subtraction angiography.

symptoms, objective diagnostic tests were performed; lung scintigraphy was routinely used, followed by pulmonary angiography if required.

Lung Scintigraphy

All patients initially underwent lung scintigraphy after administration of technetium-99m-labeled macroaggregates of albumin or krypton-81m gas for perfusion or ventilation images, respectively. A diagnosis of pulmonary embolism was excluded if the perfusion scan was normal. The presence of pulmonary embolism was considered proved if a high-probability lung scan was obtained (ie, a lung scan with more than one segmental perfusion defect with normal ventilation). Hence, lung scans with subsegmental perfusion defects or segmental matched ventilation-perfusion defects were classified as nondiagnostic. Patients with nondiagnostic lung scans were referred for pulmonary angiography. Angiography was performed only in those lungs where perfusion defects had been seen.

Angiographic Technique

In all patients, a local anesthetic (lidocaine hydrochloride; 20 mg/mL; Fresenius, Best, The Netherlands) was administered and a 7-F Grollman catheter (Cook, Eindhoven, The Netherlands) was introduced by using a transfemoral venous approach and the Seldinger technique. The right pulmonary artery, left pulmonary artery, or both were selectively catheterized, and 40 mL of contrast material (iohexol 300 [Omnipaque 300; Nycomed, Oslo, Norway; 300 mg of iodine per milliliter] or ioxaglate 320 [ioxaglate sodium:ioxaglate meglumine = 1:3; Hexabrix 320; Guerbet, Paris, France; 320 mg of iodine per milliliter]) was injected at a flow rate of 20 mL/sec at 600 psi (4.2 kPa), with a linear rise of 0.5 seconds. Images were obtained in anteroposterior and right posterior oblique directions in all patients. More series were obtained when required, and the catheter was positioned in lobar or segmental pulmonary arterial branches (highly selective). Angiograms were obtained at a rate of three images per second.

Between April 1991 and March 1992, conventional angiograms (Angioscope; Siemens, Erlangen, Germany) were obtained. In March 1992, the angiography unit was modernized, and so from that time until the end of the study, a DSA system (Polytron; Siemens) was used.

Angiographic Interpretation

All angiograms were interpreted on three occasions. They were interpreted immediately by the radiologist who performed the investigation. Angiography was performed by three experienced vascular radiologists (including A.J.B. and J.A.R.) in 80% of the cases and by several fellows in 20% of the cases. Cases were managed according to these immediate findings. Criteria for detecting emboli

have been previously described (21,23); embolism was diagnosed if an intraluminal filling defect or an acute cutoff of a blood vessel of 2 mm or more was seen on two views. The examination findings were considered negative if two views (anteroposterior and oblique) did not show an embolism.

After a minimum of 6 months, all angiograms were read for the second time by two experienced vascular radiologists (A.J.B., J.A.R.). The observers were blinded to information about the patients, and they read all angiograms independently. Observers had to decide whether the investigation findings were positive for pulmonary embolism, normal, or inconclusive. Furthermore, the quality of the images was scored on a scale of 1 (excellent) to 5 (inadequate). All angiograms were read a third time by the two vascular radiologists by means of consensus. When required, a third vascular radiologist's opinion was sought.

Statistical Analysis

Differences between the two groups were compared by using the χ^2 test. Image quality was analyzed by using the Mann-Whitney *U* test. Both statistical calculations were performed by using a computer program for statistical analysis (StatExact; Cytel Software, Cambridge, Mass). Differences were considered significant at $P < .05$.

The extent of disagreement between the radiologists' findings was determined by measuring the percentage of disagreement and calculating the κ statistic (24). The κ statistic is defined as the observed agreement not accounted for by chance divided by the possible agreement not accounted for by chance. This index has a range of +1.0 (perfect agreement) to -1.0 (total disagreement) (19). The κ scores for both the conventional angiographic and DSA series were analyzed to detect differences according to the method described by Kramer and Feinstein (25).

RESULTS

Patients

Of 397 patients examined, 115 patients (29%) had a normal perfusion lung scan, and 121 patients (30%) had a lung scan that indicated a high probability for pulmonary embolism. Angiography could not be performed in 31 (19%) of the remaining 161 patients (40%; percentages do not add to 100% because of rounding). Pulmonary angiography was not performed in these patients for various reasons: manifest heart failure in eight, refusal by the patient in six, pulmonary hypertension in five, inability to lie flat or severe dyspnea in four, renal failure in three, cardiac diseases or other important medical conditions in four, and death of myocardial infarction before angiography in one.

The initial findings of angiography determined whether patients underwent long-term anticoagulation therapy. On the basis of the immediate interpretation, a diagnosis of pulmonary embolism was excluded in 94 patients, and anticoagulants were withheld. Follow-up findings were obtained in all patients; no venous thromboembolism occurred in these patients. In 34 patients, angiograms depicted emboli; these patients subsequently underwent long-term anticoagulant therapy. In this group, one patient returned with scintigraphically proved recurrent pulmonary embolism; this diagnosis was excluded in four other patients with clinically suspected recurrent thromboembolism. In two patients, no definitive diagnosis could be made (inadequate angiogram). These patients received anticoagulants, and follow-up was uneventful.

Angiography

Conventional angiography was performed in 45 patients, and DSA was performed in 85 patients. Demographic information about these two groups of patients and findings at scintigraphy are given in Table 1, along with the locations of the largest emboli identified by means of consensus. There were no statistically significant differences in demographic characteristics between these two groups.

Observer findings in the assessment of conventional angiographic and DSA images are summarized in Table 2. Interobserver disagreement occurred in 20%–36% of patients in the conventional series. Disagreement occurred in 4%–11% of the patients in the DSA series. Initial diagnoses were changed after the images were reviewed by means of consensus in 20% and 12% of patients with conventional and DSA series, respectively. At the consensus reading, the two radiologists did not believe that pulmonary emboli were present in 13 patients with initial positive results, and they believed pulmonary emboli had been missed in one patient with initial negative results (this patient did not receive anticoagulants, and follow-up was uneventful). In two patients, the angiogram was considered inadequate.

Table 3 summarizes the results of analysis of interobserver agreement and gives the corresponding κ values. The DSA κ values were always better than the corresponding values for conventional pulmonary angiography.

Analysis of image quality showed that the conventional angiograms

Table 1
Demographic Characteristics of Patients Who Underwent Conventional Pulmonary Angiography and DSA

Characteristic	Conventional Angiography	DSA
Sex		
Male	25	40
Female	20	45
Mean age (y) $\pm$ standard deviation	55.1 $\pm$ 16.5	58.0 $\pm$ 17.6
Patient type		
Inpatient	17	40
Outpatient	28	45
Perfusion-scan defects		
Segmental	20 (44)	50 (59)
Subsegmental	25 (56)	35 (41)
Consensus findings		
Pulmonary embolism present	6 (13)	14 (17)
Pulmonary embolism absent	36 (80)	69 (81)
Inadequate angiogram	3 (7)	2 (2)
Location of largest embolus*		
Central	0	2
Lobar	1	5
Segmental	4	5
Subsegmental	1	2

Note.—Numbers in parentheses are percentages.

* Multiple peripheral emboli were also shown in all patients, but only the largest emboli were counted.

Table 2
Correlation of Findings of Pulmonary Embolism

Findings	Conventional Angiography				DSA			
	Positive	Negative	Inconclusive	Total	Positive	Negative	Inconclusive	Total
Consensus								
Immediate								
Positive	5	6	1	12	14	7	1	22
Negative	1	30	1	32	0	61	1	62
Inconclusive	0	0	1	1	0	1	0	1
Observer 1								
Positive	6	6	0	12	13	2	0	15
Negative	0	27	0	27	1	67	0	68
Inconclusive	0	3	3	6	0	0	2	2
Observer 2								
Positive	5	4	0	9	14	2	0	16
Negative	1	31	1	33	0	65	0	65
Inconclusive	0	1	2	3	0	2	2	4
Observer 2								
Observer 1								
Positive	5	8	0	13	13	2	0	15
Negative	4	22	1	27	3	63	2	68
Inconclusive	0	3	2	5	0	0	2	2

Table 3
Observer Agreement and κ Values in Conventional Angiographic and DSA Series

Comparison of Findings	Agreement (%)	κ Statistic	P*
Conventional angiography			
Immediate vs consensus	80.0	0.50	> .200
Observer 1 vs consensus	80.0	0.58	< .030
Observer 2 vs consensus	84.4	0.59	< .060
Observer 1 vs observer 2	64.5	0.28	< .003
DSA			
Immediate vs consensus	88.2	0.66	> .200
Observer 1 vs consensus	96.4	0.89	< .030
Observer 2 vs consensus	95.3	0.88	< .060
Observer 1 vs observer 2	91.8	0.77	< .003

* Significance of the difference in the κ statistic between conventional angiography and DSA.

were considered excellent in 16 of 45 patients (36%), good in 18 of 45 (40%), moderate in six of 45 (13%), adequate in two of 45 (4%), and inadequate in three of 45 (7%). DSA images were considered excellent in 49 of 85 patients (58%), good in 23 of 85 (27%), moderate in seven of 85 (8%), adequate in four of 85 (5%), and inadequate in two of 85 (2%). This difference in image quality between DSA and conventional angiography was statistically significant ($P = .02$).

DISCUSSION

Pulmonary angiography is generally regarded as the standard of reference in the diagnosis of pulmonary embolism. However, its application in a more select group of patients in whom the results of noninvasive methods have been nondiagnostic has been less well evaluated (21,22). In these patients, there is a high prevalence of comorbid conditions, such as cardiac and chronic pulmonary diseases, which negatively influence radiographic and scintigraphic interpretation (8,26,27). Furthermore, angiography itself may be more difficult to perform because of the relatively poor condition in these patients, who often also have pulmonary hypertension (21,28,29).

DSA has various advantages compared with conventional angiography. First, it allows the overlapping projection of other anatomic structures in the chest to be virtually eliminated. At the same time, anatomic background may be supplied, resulting in two separate images of the same area. This can improve the differentiation of abnormal and normal findings. Second, the amount of contrast material required may be reduced. According to a recent report, injection of 25% less contrast material still gives excellent imaging results (30). Furthermore, this reduction in contrast material reduces the risk of acute heart failure in severely compromised patients (28).

Previously, intravenous DSA techniques have been evaluated without much success (31,32). The main problem with intravenous DSA is related to motion artifacts, which occur as a result of the increased breath-hold time required in patients who often have dyspnea. Furthermore, the dilution of intravenous contrast material results in poor opacification of the smaller pulmonary arteries. Selective intraarterial DSA has the advantages of subtraction without the disadvantages associated with intravenous

DSA. The results of our study clearly show that DSA results in superior image quality and improved interobserver agreement compared with conventional angiography.

It should be realized, however, that image quality and consistency of reporting are only two factors that can be used to determine the value of an investigative technique. Another very important factor is the accuracy of the technique (pulmonary angiography), which was not primarily assessed in this study. Although there was no evidence of recurrent thromboembolism in the patients with initial normal findings, small emboli could have gone unnoticed. Disease in one patient whose angiogram initially was interpreted as normal and later was judged by means of consensus to show embolism remained untreated without evidence of recurrent embolism. Nevertheless, if one considers the consensus interpretation to be the final diagnosis, then fewer DSA diagnoses than conventional angiographic diagnoses were reversed. Hence, it appears that DSA may be more accurate.

One could argue that smaller emboli are more likely to go unnoticed than larger emboli. We evaluated the location and size of thrombi in all angiograms and found that the distribution was similar in the conventional and DSA groups. The improved interobserver agreement in the DSA group was not the result of larger, more easily identifiable emboli.

Compared with previous studies (21,22), our study showed a relatively high rate of interobserver disagreement (20%–36%) in the interpretation of conventional angiograms. In two other studies that used conventional selective arteriography, interobserver agreement was 81% and 86%. This difference could be due to the fact that the previous studies involved patients with clinically suspected pulmonary embolism; in our series, only patients with suspected pulmonary embolism and nondiagnostic results at lung scanning underwent angiography. This selection of "worst" cases is important when one wants to use angiography as a final, definitive diagnostic test in the diagnostic work-up of patients with suspected pulmonary embolism. The interpretation of intraarterial DSA images was clearly easier in this subgroup of patients, as indicated by the interobserver agreement of more than 88%.

In a large proportion of patients with pulmonary embolism who underwent conventional angiography, the diagnosis was changed when the images were interpreted a second time. This high number of false-positive initial reports may be due to the readers' fear of missing pulmonary emboli. Furthermore, 20% of examinations were performed by less experienced radiologists who may have had less confidence in their abilities. Although use of DSA did not result in a statistically significant decrease in the number of false-positive reports, there was a 45% reduction. These findings suggest that double reading of angiograms by two, preferably experienced, radiologists could reduce the unnecessary use (and subsequent bleeding risks) of anticoagulants in patients who do not have pulmonary embolism.

In conclusion, selective intraarterial DSA is superior to conventional pulmonary angiography in terms of image quality and interobserver agreement in the diagnosis of pulmonary embolism. In patients with nondiagnostic results at lung scanning, DSA is the technique of choice. ■

Acknowledgment: The authors thank J. Oosting, BSc, for valuable statistical advice.

References

- Anderson FA Jr, Wheeler HB, Goldberg RJ, et al. A population-based perspective of the hospital incidence and case-fatality rates of deep vein thrombosis and pulmonary embolism: the Worcester DVT study. *Arch Intern Med* 1991; 151:933–938.
- Van Beek EJR, Büller HR, van Everdingen JJE, Zwijsenburg A, ten Cate JW. Diagnostic management of suspected pulmonary embolism in the Netherlands: results from a questionnaire (abstr). *Thromb Haemostasis* 1991; 65:1171.
- PIOPED investigators. Value of the ventilation-perfusion scan in acute pulmonary embolism: results of the Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED). *JAMA* 1990; 263:2753–2759.
- Hull RD, Hirsh J, Carter CJ, et al. Diagnostic value of ventilation-perfusion lung scanning in patients with suspected pulmonary embolism. *Chest* 1985; 88:819–828.
- Kelley MA, Carson JL, Palevsky HI, Schwartz JS. Diagnosing pulmonary embolism: new facts and strategies. *Ann Intern Med* 1991; 114:300–306.
- Oudkerk M, van Beek EJR, van Putten WLJ, Büller HR. Cost-effectiveness analysis of various strategies in the diagnostic management of pulmonary embolism. *Arch Intern Med* 1993; 153:947–954.
- Hull RD, Raskob GE, Ginsberg JS, et al. A non-invasive strategy for the treatment of patients with suspected pulmonary embolism. *Arch Intern Med* 1994; 154:289–297.
- Stein PD, Hull RD, Saltzman HA, Pineo G. Strategy for diagnosis of patients with suspected acute pulmonary embolism. *Chest* 1993; 103:1553–1559.
- Kipper MS, Moser KM, Kortman KE, Ashburn WL. Longterm follow-up of patients with suspected pulmonary embolism and a normal lung scan. *Chest* 1982; 82:411–415.
- Hull RD, Raskob GE, Coates G, Panju AA. Clinical validity of a normal perfusion lung scan in patients with suspected pulmonary embolism. *Chest* 1990; 97:23–26.
- Van Beek EJR, Kuyper PMM, Schenk BE, Brandjes DPM, ten Cate JW, Büller HR. A normal perfusion lung scan in patients with clinically suspected pulmonary embolism: frequency and clinical validity. *Chest* 1995; 108:170–173.
- Cheely R, McCartney WH, Perry JR, et al. The role of noninvasive tests versus pulmonary angiography in the diagnosis of pulmonary embolism. *Am J Med* 1981; 70:17–22.
- Spies WG, Burstein SP, Dillehay GL, Vogelzang RL, Spies SM. Ventilation-perfusion scintigraphy in suspected pulmonary embolism: correlation with pulmonary angiography and refinement of criteria for interpretation. *Radiology* 1986; 159:383–390.
- Hull RD, Raskob GE, Carter CJ, et al. Pulmonary embolism in outpatients with pleuritic chest pain. *Arch Intern Med* 1988; 148:838–844.
- Gray HW, McKillop JH, Bessent RG, Fogelman I, Smith ML, Moran F. Lung scanning for pulmonary embolism: clinical and pulmonary angiographic correlations. *Q J Med* 1990; 77:1135–1150.
- Morrell NW, Seed WA. Diagnosing pulmonary embolism. *Br Med J* 1992; 304:1126–1127.
- Novelline RA, Baltarowich OH, Athanasoulis CA, et al. The clinical course of patients with suspected pulmonary embolism and a negative pulmonary arteriogram. *Radiology* 1978; 126:561–567.
- Dalen JE, Brooks HL, Johnson LW, et al. Pulmonary angiography in acute pulmonary embolism: indications, techniques, and results in 367 patients. *Am Heart J* 1971; 81:175–185.
- Mills SR, Jackson DC, Older RA, et al. The incidence, etiologies, and avoidance of complications of pulmonary angiography in a large series. *Radiology* 1980; 136:295–299.
- Hull R, Hirsh J, Carter C, et al. Pulmonary angiography, ventilation lung scanning, and venography for clinically suspected pulmonary embolism with abnormal perfusion lung scan. *Ann Intern Med* 1983; 98:891–899.
- Stein PD, Athanasoulis C, Alavi A, et al. Complications and validity of pulmonary angiography in acute pulmonary embolism. *Circulation* 1992; 85:462–468.
- Quinn MF, Lundell CJ, Klotz TA, et al. Reliability of selective pulmonary arteriography in the diagnosis of pulmonary embolism. *Am J Radiol* 1987; 149:469–471.
- Bookstein JJ. Segmental arteriography in pulmonary embolism. *Radiology* 1969; 93:1007–1012.
- Sackett DL, Haynes RB, Tugwell P. The interpretation of diagnostic data. In: Sackett DL, Haynes RB, Tugwell P, eds. *Clinical epidemiology, a basic science for clinical medicine*. Boston, Mass: Little, Brown, 1983; 59–138.
- Kramer MS, Feinstein AR. Clinical biostatistics: the biostatistics of concordance. *Clin Pharmacol Ther* 1981; 29:111–123.
- Alderson PO, Biello DR, Sachariah KG, Siegel BA. Scintigraphic detection of pulmonary embolism in patients with obstructive pulmonary disease. *Radiology* 1981; 138:661–666.
- Stein PD, Coleman RE, Gottschalk A, et al. Diagnostic utility of ventilation/perfusion lung scans in acute pulmonary embolism is not diminished by pre-existing cardiac or pulmonary disease. *Chest* 1991; 100:604–606.
- Nicod P, Peterson K, Levine M, et al. Pulmonary angiography in severe chronic pulmonary hypertension. *Ann Intern Med* 1987; 107:565–568.
- Perlmutter LM, Braun SD, Newman GE, Oke JE, Dunnick NR. Pulmonary arteriography in the high-risk patient. *Radiology* 1987; 162:187–189.
- Van Rooij WJJ, den Heeten GJ, Sluzewski M. Pulmonary embolism: diagnosis in 211 patients with use of selective pulmonary digital subtraction angiography with a flow-directed catheter. *Radiology* 1995; 195:793–797.
- Piers DB, Verzijlbergen F, Westermann CJJ, Ludwig JW. A comparative study of intravenous digital subtraction angiography and ventilation-perfusion scans in suspected pulmonary embolism. *Chest* 1987; 91:837–843.
- Pond GD, Oviit TW, Capp MP. Comparison of conventional pulmonary angiography with intravenous digital subtraction angiography for pulmonary embolic disease. *Radiology* 1983; 147:345–350.