Acute Pulmonary Thromboembolism*
Comparison of the Diagnostic Capabilities of Conventional Film-Screen and Digital Angiography

Tony P. Smith, MD; J. Mark Ryan, MD; and Brian K. Brodwater, MD†

Study objective: To compare digital to conventional film-screen pulmonary angiography for the diagnosis of acute pulmonary embolism (PE) in a clinical population.

Design: Retrospective review of patient data, ventilation/perfusion (V/Q) lung scintigraphy reports, and pulmonary angiographic reports.

Setting: University hospital, division of interventional radiology.

Patients and methods: Patient data from 307 film-screen and 266 digital angiograms were analyzed for demographics, V/Q lung scintigraphy findings, and pulmonary artery pressures to define patient populations. The interpretations of film-screen pulmonary angiography were then compared with digital angiography interpretations for the entire group of interventional radiologists as well as the two interventionalists who practiced throughout the study interval to determine any difference in rates of diagnosis of acute PE between the two techniques.

Results: There was no significant difference between the patient populations studied by film-screen or digital techniques for the data reviewed. Digital angiography utilized significantly more contrast material (digital, 173 mL; film-screen, 145 mL; p < 0.01) and a greater number of angiographic views (digital, 3.6 views per patient; film-screen, 3.4 views per patient; p = 0.04) when compared with film-screen angiography. There was no difference between the two techniques in the rates of diagnosis of acute PE, for individual radiologists or overall.

Conclusions: Digital and film-screen pulmonary angiography possess equivalent diagnostic capabilities for acute PE as used in a clinical setting.

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Key words: comparative studies; digital subtraction angiography; pulmonary angiography; pulmonary embolism

Abbreviations: PE = pulmonary embolism; PIOPED = Prospective Investigation of Pulmonary Embolism Diagnosis; V/Q = ventilation/perfusion

Pulmonary angiography is regarded as the imaging standard of reference for the diagnosis of pulmonary embolism (PE) and serves as the basis by which other imaging studies, most notably helical CT scanning, are evaluated.1–4 The second version of the Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) has recently begun patient recruitment with the specific aim of determining the sensitivity, specificity, and positive and negative predictive values of contrast-enhanced helical CT scanning for the diagnosis of acute PE (PIOPED II study protocol). The study uses a composite reference test for venous embolic disease, including digital pulmonary angiography. The purpose of PIOPED II is to determine the extent to which helical CT scanning can serve as a minimally invasive test for PE, thereby eliminating or reducing the need for pulmonary angiography.

Although it serves as the “gold standard” for the diagnosis of PE, there are clinical concerns with pulmonary angiography. Even though it is quite safe, pulmonary angiography is still an invasive procedure and can be time-consuming for both the patient and interventional radiologist, particularly when performed using standard film-screen techniques.5 Interobserver variability has been reported to be quite high, particularly for subsegmental emboli.6–8 Stein et al9 have reviewed pulmonary angiography data from the first PIOPED trial and found conventional film-screen pulmonary angiography to be imprecise for the diagnosis of PE that is limited to subsegmental arteries. CT scanning is also less accurate for the detection of subsegmental thrombus, and angiography is often used to finalize the diagnosis of PE.
Despite these concerns with even conventional film-screen angiography, digital pulmonary angiography is widely applied for the diagnosis of PE. Indeed, digital techniques have become so dominant in the marketplace that most major equipment manufacturers now offer film-screen capabilities only as an option. This has, unfortunately, been based on ease of imaging and the inferred clinical equivalency of the two techniques, without substantial published data. Two controlled comparative series published in 1998 reported that digital was at least equivalent to film-screen angiography. However, these studies were performed with limited film-screen views of a single lung in small patient series. Although this certainly allowed side-to-side image comparison, it did not permit the comparison of clinical results for the two techniques. For example, independent interpreters were only provided with photographed digital images for comparison. Digital angiography is clinically interpreted with the aid of a workstation, which affords essential image manipulation.

In our own institution, pulmonary angiography has been performed solely by digital techniques since 1994. Prior to that time, pulmonary angiography was performed using exclusively conventional film-screen techniques. In addition, helical CT scanning was not utilized for the diagnosis of acute PE in our institution until 1997. This provides a population of patients that allows retrospective comparison of the two angiographic techniques. Given the paucity of clinical data regarding digital vs film-screen pulmonary angiographic techniques and the important role that digital pulmonary angiography has assumed as the imaging standard of reference for the diagnosis of PE, especially in light of the PIOPED II findings, we believe there is a need for the publication of data comparing the two techniques as utilized in a clinical setting. With this in mind, we assessed our own experience with digital pulmonary angiography for acute PE since conversion from the conventional film-screen approach to determine any significant differences in diagnostic trends between the two techniques as applied to a large clinical population.

**Materials and Methods**

Pulmonary angiography in our institution was performed using standard film-screen techniques until November 1993, when state-of-the-art digital equipment was installed. After January 1, 1994, all angiograms were performed using digital techniques. The records of 388 consecutive film-screen pulmonary angiograms performed between January 1, 1991, and June 30, 1993, and of 330 consecutive digital pulmonary angiograms performed between January 1, 1994, and June 30, 1996, were collected for analysis. In order to compare populations, the following information was collected: patient age, sex, interpretation of ventilation/perfusion (V/Q) scintigraphy, indications for pulmonary angiography, and pulmonary artery pressures at angiography. Angiographic studies were excluded if requested for indications other than the possibility of acute PE, or if these studies had not been preceded by V/Q lung scintigraphy within 48 h, as scintigraphy was being used for patient population comparison only. Using these criteria, a total of 81 studies were removed from the film-screen group (75 for the absence of a proximate V/Q scan, and 6 for indication), and 64 studies were removed from the digital group (58 for the absence of a proximate V/Q scan, and 6 for indication). The final compilation of 573 studies (307 film-screen, 266 digital) formed the study cohort.

V/Q lung scintigraphy was performed in standard fashion. For the ventilation study, approximately 20 mCi $^{133}$Xe was administered by inhalation, and breath-hold, equilibrium, and washout phases were obtained in a posterior projection. For perfusion imaging, 4 mCi $^{99m}$Tc-labeled macroaggregated albumin was injected IV, and anterior, posterior, and oblique projections were obtained. V/Q lung scintigrams were interpreted by seven subspecialized nuclear medicine physicians. All studies were reported as indicating a low, intermediate, or high probability for PE according to the PIOPED criteria.

Film-screen angiography was performed (GE MSI 1250; General Electric Medical Systems; Milwaukee, WI), using an AOT 35 × 35-cm serial film changer (Elema-Schonander, Solna, Sweden) or two Poly Diagnost A/U units (Philips Medical Systems, Inc; Bothell, WA) each equipped with a 35 × 35-cm serial film changer (Puck UD 4; Elema-Schonander). Images were routinely obtained at three frames per second for the initial 3 to 5 s with delayed imaging at the discretion of the interventional radiologist. Although all units had biplane filming capabilities, only single-plane imaging was performed during the study interval. Digital angiography was performed on one of two identical devices (Philips Integris V3000) with single-plane 38-cm image intensifiers using a 1,024 × 1,024-pixel digital matrix. Rates of image acquisition were at the discretion of the interventional radiologist and ranged from three to six images per second until adequate visualization of the venous phase. The pulmonary angiographic report at our institution consists of the following seven sections: patient history, type of procedure performed, access site for catheterization, type and amount of contrast material, interventional radiologist(s) performing the procedure, complications, and angiographic findings.

For pulmonary angiography, a common femoral vein approach was used in 303 cases (99%) for film-screen angiography and 262 cases (88%) for digital angiography. Access was achieved via the jugular veins in five patients and via the brachial veins in three patients. A 7F pigtail catheter (Grollman or Van Aman; Cook, Inc; Bloomington, IN) was initially placed in either the right or left pulmonary artery in all patients. Unless otherwise warranted, angiography was terminated once PE was definitively diagnosed. Therefore, only one side may have been studied if PE was diagnosed in the first lung studied. Unilateral studies were performed in 47 patients (15%) undergoing film-screen angiography and in 48 patients (18%) undergoing digital angiography. Film-screen techniques were used in a total of 567 lungs (307 patients) and digital techniques were used in 484 lungs (266 patients). At least one angiographic view was performed in all patients. The total number of views per patient ranged from one to six (mean, 3.4 views) for film-screen angiography and one to six (mean, 3.6 views) for digital angiography. The choice of angiographic views was at the discretion of the angiographer but always included an anterior-posterior view for the right lung and a right anterior oblique view for the left. Subselective catheterization beyond the main right or left pulmonary artery was performed in 42 patients (14%) with film-screen angiography.
and in 31 patients (12%) with digital angiography. When subselective angiography was performed, unilateral pulmonary angiography only was performed in six patients in the film-screen group and seven patients in the digital group.

Iopamidol (61%) was the contrast material utilized throughout. The total amount of contrast material for the procedure was recorded, but the amounts for individual angiographic injections was not. The rate of contrast material injection was at the discretion of the angiographer based on test injections. The total amount of contrast material administered was the amount the angiographer determined to be necessary to complete the clinical study. Ten patients received >300 mL contrast material for the completion of pulmonary angiography. One patient undergoing film-screen angiography received 300 mL contrast material. Six patients undergoing digital angiography required 300 mL, and one patient each received 350, 430, and 600 mL contrast material. Regarding the latter three patients, all required subselective angiography, and the first two patients (ie, those receiving 350 and 450 mL) also underwent inferior vena cava filter placement. The final patient (600 mL) required multiple angiograms during unsuccessful intra-arterial thrombolytic therapy as a life-saving measure for massive PE.

Angiographic data tabulated for this study included pertinent patient history, type of study performed, total amount of contrast material, complications, radiologists performing the procedure, a summary of the techniques, and radiographic findings. All angiograms were performed by attending interventional radiologists (n = 10); two radiologists performed studies over the entire time interval of data collection, allowing a comparison of both techniques as conducted by a single interventionalist.

Statistical analyses of the data were performed using χ² and standard t tests. All tests were considered statistically significant at p values of ≤0.05.

RESULTS

There were no significant differences in the basic constitution of the digital and film-screen pulmonary angiography patient groups. There were 159 men (52%) and 148 women (48%) in the film-screen group, compared with 122 men (46%) and 144 women (54%) in the digital group (p = 0.61). Age ranges for the film-screen and digital groups were 15 to 89 years (mean, 58 years) and 19 to 93 years (mean, 57 years), respectively (p = 0.17). V/Q interpretations prior to angiography were similarly distributed among the categories of low, intermediate, and high probability for patients studied by film-screen angiography (26%, 66%, and 7%, respectively) and for patients studied by digital angiography (29%, 62%, and 9%, respectively; p = 0.91) [Table 1]. The imaging results comparing film-screen and digital angiography in the diagnosis of acute PE are given in Table 1. The mean systolic/diastolic pulmonary artery pressure was 38/15 mm Hg for the film-screen group and 35/13 mm Hg for the digital group (systolic, p = 0.26; diastolic, p = 0.17). PE was diagnosed in 25% of patients in the digital group and in 21% in the film-screen group (p = 0.43). There were significant differences in the amount of contrast used for digital angiographic procedures (mean, 173 mL) compared with film-screen angiographic procedures (mean, 145 mL; p < 0.01), and also in the number of angiographic views obtained by digital angiography (mean, 3.6 views per patient) vs film-screen angiography (mean, 3.4 views per patient; p = 0.04). There was, however, no difference between the two techniques regarding the need for superselective catheterization and angiography (p = 0.28).

For both interventional radiologists who interpreted film-screen and digital pulmonary angiography during the entire study interval, there was no significant difference between the two techniques in terms of the rates of diagnosis of acute PE for either interventionalist (p = 1.00; p = 0.44) [Table 1].

DISCUSSION

Digital angiography has practical advantages over film-screen angiography. The examination is less
time-consuming, eliminating the need for scout filming and film processing prior to image review. The images can be viewed as an acquired movie or digital cine loop in addition to static images. Many postprocessing features are available, including subtracted or nonsubtracted modes. Despite these advances, very few data are available to compare digital pulmonary angiography and film-screen techniques for the diagnosis of acute PE. Certainly, such data are critical. Pulmonary angiography is being used for increasingly difficult situations in which a confident diagnosis cannot be reached by other imaging modalities. As with PIOPED II, pulmonary angiography is also being used for the validation of less invasive imaging modalities.

We performed a comparison of our pulmonary angiography data before and after the institution of digital imaging to determine whether there were any differences in diagnostic results between these two techniques when applied to a large clinical population. This allowed comparison between film-screen and digital pulmonary angiography in a clinical setting. Both techniques were used to their fullest capacity and a diagnosis was reached in all patients. The study interval (1991 to 1996) was chosen for two reasons. This was the time in which we converted from film-screen to state-of-the-art digital equipment. It was also prior to the application of CT scanning for the diagnosis of PE in our institution.

We found no significant difference in the rates of diagnosis of acute PE between film-screen and digital angiography. Indeed, the numbers were nearly identical. Two interventional radiologists were present throughout both study intervals. Although one of those interventionists tended to perform a greater number of pulmonary angiograms than the other, both demonstrated substantial consistency in their interpretations before and after conversion to digital imaging, and intraobserver agreement was high for film-screen and digital angiographic techniques for the diagnosis of PE. It seems clear that digital angiography is essentially equivalent to film-screen angiography in the diagnosis of acute PE within our patient population and for the two interventionalists under study.

There were two significant differences between film-screen and digital angiography. Digital studies resulted in a greater number of angiographic views per patient and in a greater volume of contrast material compared with film-screen angiography. Because film-screen techniques have greater inherent resolution, providing better anatomic detail, and are less subject to artifacts, particularly related to breathing, film-screen angiography may require fewer angiographic runs. However, we believe the differences are more likely related to the speed and ease of use of digital techniques. Film changers, chemical processing, and film hanging burden film-screen angiography. When using film-screen techniques, an interventional radiologist may be willing to make decisions on fewer images rather than prolonging the procedure for the sake of absolute certainty. This is particularly pragmatic as patients in whom PE is suspected are often very ill and can be clinically unstable, placing a premium on the expeditious completion of angiographic studies. Because additional angiographic views can be obtained and interpreted in seconds using digital techniques, we believe that many interventional radiologists are prone to proceed with additional runs to confirm their diagnosis. In our practice, contrast use is directly related to the number of angiographic runs because we have continued to use full-strength contrast material for digital angiography rather than diluting the contrast, as has been advocated.

There are obvious deficiencies with this study. The validity of the results is, of course, predicated on the demonstrated similarities between the two populations with respect to basic constitution. There can be no accounting for possible changing trends in pulmonary embolic disease during the study interval. We do not believe there have been significant changes in referral patterns, and there was, overall, no difference in the demographic data, including age and sex distributions, for the two populations. V/Q scintigraphy was clearly the same, and pulmonary artery pressures were nearly identical. Despite these similarities, this does not replace a prospectively controlled study. Ideally, a comparative assessment of film-screen and digital angiography would be conducted as a prospective clinical trial. Such a trial could be performed in two forms as follows: both techniques could be performed fully in all patients; or patients could be randomly allocated to one test or the other. Certainly, both techniques could not be fully completed in any single group of patients, as the amount of contrast material needed would be prohibitively high, particularly for patients who are very ill. A controlled, randomized study is theoretically possible, but, practically, it would be extremely difficult to achieve given a relatively slow accrual rate of angiography candidates (in light of less invasive imaging techniques) and the nearly complete conversion of many laboratories such as ours to digital imaging. We believed, therefore, that reporting our retrospective series with data collected as carefully as possible was an acceptable alternative.

Digital pulmonary angiography has been compared with film-screen angiography in a small number of studies. The first direct comparison with film-screen angiography for the detection of acute PE was in an animal model. Although film-screen
techniques identified a greater number of emboli, there were no significant differences in the sensitivity or positive predictive value for the two techniques, or in the intraobserver agreement among readers. These results were, however, obtained under the following idealized circumstances: the animals were anesthetized, and there were no limits for radiation and contrast material dosage or, indeed, for the time allotted for the performance of the study and its interpretation. In 1996, van Beek et al performed a retrospective review of 130 patient studies and found that interobserver agreement was better with digital techniques than with film-screen techniques. Although conclusions from this study are limited by relatively small numbers, this comparison of the two techniques was made in a clinical setting.

Two prospective studies have been published comparing film-screen and digital pulmonary angiograms within the same patient in a clinical setting. In one study, the authors concluded that film-screen and digital angiography had essentially equivalent diagnostic efficacy for PE, and the reviewers’ confidence was significantly better for digital. A similar study indicated that digital angiography had a higher sensitivity than film-screen for the detection of PE, and the authors concluded that digital angiography was a reasonable alternative to film-screen angiography in the diagnosis of PE. Both of the studies concluded that digital pulmonary angiography was at least equivalent to film-screen angiography. Although these were both well-planned and well-executed studies, both were small in patient numbers (80 and 36 patients) and limited the comparative study (film-screen) to a single lung with only one or two projections. Although this certainly allows direct comparison of both techniques in a single patient, it does not necessarily compare the two techniques as they are conducted and interpreted in a clinical context. The current study has the advantage of comparing clinical populations in numbers larger than would probably be possible on a prospective basis.

In conclusion, we found no difference in the rates of diagnosis of acute pulmonary embolism between digital and film-screen pulmonary angiography when compared retrospectively in a large clinical patient population. Based on these findings, we believe that digital pulmonary angiography can be utilized as confidently as film-screen angiography, both as a clinical diagnostic tool and as an imaging reference for less invasive studies.

References
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