Identification of Pulmonary Emboli in the Dog: Comparison of Angioscopy and Perfusion Scanning

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SUMMARY Fifteen dogs were studied by perfusion scan, angioscopy and autopsy. In 10, emboli were formed in leg veins and released before study; five dogs were not embolized and served as controls. In controls, angioscopy disclosed no emboli, perfusion scans were normal after angioscopy and autopsy disclosed no emboli. Among the embolized dogs, 23 emboli were identified at autopsy. Perfusion scans disclosed 23 defects, but in three dogs there was a disparity between scan and autopsy localization. Angioscopy identified 21 of the 23 autopsy-defined emboli and localized them correctly; two emboli in vessels less than 1 mm in diameter were not visualized. Angioscopy may provide a useful new approach in animal investigations of pulmonary embolism and perhaps, after additional study, in selected patients.

THE SPECIFICITY, sensitivity and risk/benefit ratio of techniques for diagnosing pulmonary embolism are controversial. Direct in vivo visualization of emboli might help resolve certain elements of this controversy in animal investigations and in selected patients. We have described development of a fiberoptic device, the angioscope, for direct, in vivo visualization of the right-heart chambers and the pulmonary vasculature. Among the potential diagnostic applications of this device is the direct visualization of pulmonary emboli. To evaluate this application, we studied 10 dogs with experimentally induced emboli and five nonembolized controls with angioscopy, lung perfusion scans and autopsy.

Methods

Ten dogs were sedated with pentobarbital (25 mg/kg), intubated and mechanically ventilated at tidal volumes of 15 ml/kg. To produce thrombi, we occluded the femoral vein by inflating the balloon of a Swan-Ganz catheter passed retrograde from the paw and injecting 10 NIH units of bovine thrombin proximal to the balloon. After "aging" in situ for 30 minutes, the thrombi were embolized by deflating the balloon and gently milking the leg manually. This technique consistently (> 95%) produces thrombi and emboli.

Within 10-15 minutes after embolization, the angioscope was inserted through a right jugular venotomy and guided to the pulmonary arterial system under direct visualization. Its position was periodically confirmed by fluoroscopy. The locations of all emboli were recorded by the angiologist during the procedure, and the angioscope was removed. The entire procedure, from venotomy to angioscope removal, lasted approximately 20 minutes.

Next, 1 mCi of 99mTc-albumin microspheres was injected intravenously and perfusion scans were obtained in anterior, posterior and both lateral positions. The scans were interpreted by one of the authors, who was unaware of the angiographic results.

Finally, the dogs were heparinized and sacrificed, and postmortem examination was performed immediately. Dissection was carried down to arterial branches of 1 mm in diameter, and the presence of all emboli was recorded by a third member of the investigative team.

Five control dogs were studied in the same way as the embolized dogs, except that venous thrombi were not induced. The control scans were interpreted along with those from the embolized dogs.
The angioscope used in this study is 80 cm long and 4 mm in diameter (fig. 1). The distal end can be flexed 90° by a lever at the proximal end. The distal end is covered by a transparent polyurethane balloon (fig. 2) that can be inflated with carbon dioxide or saline from a 0.8-mm internal channel. The balloon is secured to the angioscope with 6/0 Tevdek (Teflon-coated nylon) suture. A 300W xenon light source is used. The angioscope is inserted through a small incision in the jugular vein. When inflated and positioned so it touches the structure to be visualized, the balloon displaces the blood and provides a clear view of the structure. Using this technique, the angioscope is passed under direct visualization into the right side of the heart and into the pulmonary vasculature.

Structures on the right side of the heart can be clearly visualized (figs. 3 and 4). The pulmonary vasculature can be systematically examined in the same manner that the bronchi can be examined with the fiberoptic bronchoscope. The angioscope can be passed into pulmonary arterial branches as small as 4 mm in diameter and side branches to smaller vessels can be seen, but not entered. Figure 5 shows the interior of a normal pulmonary artery in a dog. The intima is pale and the blood in front of the balloon is bright red. In prior studies, emboli have been readily visualized (fig. 6).

Before this study, we examined the right heart and pulmonary arterial vasculature with the angioscope in more than 100 dogs. The only morbidity encountered was transient arrhythmias during passage of the angioscope through the right cardiac chambers.

**Results**

On perfusion lung scans, 23 lobar and segmental defects were seen in the 10 dogs with induced emboli (table 1). At postmortem examination, 23 emboli were discovered. In dogs 4 and 8, one large central embolus found at autopsy produced two lobar perfusion defects (fig. 7). In dog 10, three sublobar emboli found at autopsy produced one lobar defect on perfusion scan.

At angioscopy, 21 of the 23 emboli discovered at autopsy were visualized. The two emboli not detected (dogs 1 and 3) were in vessels too small (1 mm) to be reached by the angioscope.

In the five control dogs, no thromboemboli were seen during angioscopy and the perfusion scans after angioscopy were considered normal.
Discussion

Lung scanning and pulmonary angiography are the major techniques of diagnosing pulmonary embolism; each has advantages and disadvantages.1-8 Perfusion lung scanning is noninvasive, low-risk and sensitive, but nonspecific. Adding ventilation lung scanning provides increased specificity, but to a debatable degree. Pulmonary angiography is invasive, and quality performance and interpretation of angiography are not universally available. All three techniques must be performed and interpreted by experienced persons to provide optimal diagnostic yield.

In this study, we focused on whether angioscopy could provide reliable visualization and localization of fresh emboli. Our results indicate that visualization can be accomplished reliably and without significant morbidity. In the hands of an experienced angioscopist, 21 of the 23 emboli documented at autopsy were visualized, and the emboli were accurately localized. Whereas the perfusion scan cannot differentiate between a single large embolus obstructing blood flow to two lung regions and two or more smaller emboli causing such obstruction, angioscopy, like angiography, can do so. For example, in dog 10, a “lobar” perfusion defect on scan was found, at autopsy and by

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<th>Table 1. Location of Pulmonary Emboli Detected by Angioscopy, Perfusion Lung Scan and Autopsy</th>
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Abbreviations: RLL = right lower lobe; RUL = right upper lobe; LLL = left lower lobe; LUL = left upper lobe; RPA = right pulmonary artery; LPA = left pulmonary artery.
angioscopy, to be caused by three sublobar emboli. In dogs 4 and 8, angioscopy and autopsy showed that a central embolus was responsible for "two-lobe" occlusion by scan.

On the other hand, the 4-mm angioscopy did not detect smaller emboli that lodged beyond its potential field of view; and we did not visualize two emboli in vessels less than 1 mm in diameter.

The only morbidity we encountered was transient, untreated arrhythmias as the angioscope traversed the right-heart chambers, as in a previous study.7 We are now investigating the specific hemodynamic responses to angioscopy in embolized and nonembolized dogs. No hemodynamic or gas exchange alterations have been observed in nonembolized dogs. Small increases in mean arterial pressure, cardiac output and heart rate (but not in pulmonary artery pressure) have occurred during angioscopy in embolized dogs. Transient arrhythmias have occurred in both groups.

The extrapolation of these findings to assessment of the angioscope's potential diagnostic role in human embolic disease would be, at this juncture, speculative and awaits further investigation. However, the angioscope can be used safely in humans, as shown by Tanabe et al.,8 who used a similar instrument for cardiac diagnostic purposes in 45 patients, without significant morbidity.

Lung scans and angiograms in the diagnosis of experimental and clinical pulmonary embolic disease have been compared.1-3,6 These investigations have shown the advantages and disadvantages of both approaches in terms of specificity, sensitivity, risk and patient access. Thus, scans and angiograms are regarded as complementary approaches. Although no data comparing angioscopy and angiography are available, it seems reasonable to suggest that angioscopy could be used only when diagnostic doubt remained after scan and angiographic data were obtained or when angiography was contraindicated (e.g., hypersensitivity to contrast media).

Angioscopy has many potential uses in research, including observation of embolus resolution in vivo, both spontaneously and with direct application of thrombolytic agents. Because angioscopic observations can be repeated easily, other investigative applications are to be anticipated.

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