LETTERS TO THE EDITOR

Re: Deconvolutional Analysis In Radionuclide Quantitation of Left-to-Right Cardiac Shunts

Alderson et al. (*1*) have attempted to use deconvolutional analysis to correct for bad bolus injection in the radionuclide angiographic study of left-to-right cardiac shunts. In order to assess their methods it is important to analyze their mathematics. Their first mathematical statement is that the observed pulmonary time-activity curve, A, is the convolution of the time-activity curve of the injected bolus, B, and that of the ideal pulmonary activity. In the derivation of this equation three assumptions are required:

1. Bolus time-activity does not change, apart from a time delay, in passage to the lungs from the region of interest, R_B, that is used to derive the bolus time-activity curve.
2. Bolus activity is a constant throughout its region of interest, R_B, at any given time.
3. Pulmonary activity (either observed or ideal, since each implies the other) is a constant throughout its region of interest, R_L, at any given time.

Conversely, if the convolution equation is assumed to be true, it can be shown that the three conditions must hold. It is essential, then, that the limitations of these assumptions be assessed.

The assumption that the observed pulmonary activity, A, is constant in a chosen region, R_L, at any time can be checked by subdividing R_L and plotting the average activity within each subdivision against time. If the curve does not differ significantly from one subdivision to the next, the assumption may be taken as valid.

Alderson et al. (*1*) chose the superior vena cava for R_B. Even if mixing at this site is taken as thorough and uniform, the pumping action of the heart distorts the time distribution so that this R_B does not give the true time-activity curve for lung input. More precisely, assumption 1, above, is not valid. Any closely spaced sharp-bolus injections would have the summed time-activity curves markedly altered by the time the activity gets into the pulmonary artery. It is no surprise, then, that when Alderson et al. applied deconvolutional analysis for repeat sharp-bolus injections spaced closely together, results for shunting ratio were inconsistent and in cases more unreliable than when deconvolutional analysis was not used.

The optimum site for R_B is the pulmonary artery. If the time for passage of the injected bolus through the right heart is less than pulmonary circulation time, this region of interest does give the true time-activity curve for lung input. If recirculating and shunted activity overlaps too much with a very slow bolus, the bolus time-activity cannot be calculated with certainty this way. It would then be necessary to choose R_B over the superior vena cava, as Alderson et al. did, and inject the bolus in a smooth fashion. The longer it takes for the injection, the less the heart distorts its time-activity, and the more reliable the deconvolution method will be.

With this precaution, deconvolutional analysis offers a method of correction for non-spike bolus injections in the study of left-to-right cardiac shunts.

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REFERENCE

1. ALDERSON PO, DOUGLAS KH, MENDENHALL KG, et al: Deconvolution analysis of radionuclide quantitation of left-to-right cardiac shunts. *J Nucl Med* 20: 502-506, 1979

Reply

We thank Dr. Boxen for his comments, which give us the opportunity to amplify some points in our paper.

With deconvolution analysis we are trying to determine the shape of the pulmonary time-activity curve that would result from a perfect spike bolus into the patient's superior vena cava (SVC). We are *not* trying to obtain the transfer function of the lungs. If this were our goal, we would need to obtain the input function, as Dr. Boxen suggests, from a region of interest over the pulmonary artery. In fact, the transfer function of the lungs would often fail to reveal a left-to right (L-R) cardiac shunt. If the input region of interest (ROI) is over the pulmonary artery, it will contain shunt recirculation through an atrial or ventricular septal defect. Upon deconvolution of the pulmonary curve, the shunt will "deconvolute out." Thus, in practice, the pulmonary artery is not the best site to derive the pulmonary input function. However, this "disadvantage" of a pulmonary-artery ROI might be useful for distinguishing between L-R cardiac (ASD, VSD) and extra-cardiac shunts (PDA). The recirculation from a PDA will not usually affect main pulmonary activity, so a PDA shunt should not "deconvolute out" using a pulmonary-artery ROI as lung input.

We agree with Dr. Boxen's comments regarding the assumption of constant activity throughout the region of interest. In fact, that assumption is made for virtually every region of interest selected for analysis during *any* computer-assisted radionuclide study. If this assumption were not true for the SVC, it could alter the results of deconvolution. For this reason we draw a small (1-2 pixels high) ROI in the SVC in the direction of travel of the bolus.

It is true that the results obtained after deconvolution of fragmented bolus injections are not as good as those obtained with single-peak, prolonged bolus injections. As explained in the paper,

we believe this is due largely to limitations in high-frequency response caused by our data-collection frequency of 2.5 frames/sec (multipeak boluses contain a greater proportion of high frequencies than prolonged boluses). Faster sampling rates may improve our ability to deconvolute a fragmented bolus.

In our clinical trials of deconvolution analysis we have been purposely injecting a slow, smooth bolus. This minimizes the chances for a fragmented, multipeak injection and maximizes the ability of our current deconvolution algorithm to provide accurate shunt quantitation. Our initial clinical experience with the algorithm in both adult and pediatric patients has been excellent, and we hope to report it in the near future.

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Regarding Venography and Lung Scanning

After I read this superb article (*1*), I remained frustrated with regard to several points:

1. Of 19 patients with abnormal venograms and normal perfusion lung scans, eight were said to have had pulmonary embolism. In my experience no patients with pulmonary embolism have had a normal perfusion lung scan when performed within 24 hr of the occurence of embolism. Nor am I aware of any reports in the literature describing such a case. The time of study after onset of suspected pulmonary embolism was not stated in the article.

2. The article states that "47 of 102 patients were serially studied on two to four occasions," but there was no discussion of those repeat studies. When the perfusion lung scan is delayed 24 to 48 hr after occurence, if the lesion is small, all evidence of pulmonary embolism may be gone. (I have seen only one such case; however, I rarely have the opportunity to repeat lung scans after one day.) The authors report normal venograms with abnormal perfusion lung scans in five patients with pulmonary embolism. Although it certainly is possible that embolism originated at a site not amenable to diagnosis by lower-extremity venography, evidence of thrombosis and/or phlebitis may have disappeared if the study were delayed too long following onset of the pulmonary lesion. Here again it is important to know the timing of the study in relation to the clinical situation, and both results and timing of any follow-up studies that may have been obtained. I have had the opportunity to do follow-up venograms on only two patients with definite evidence for thrombosis-phlebitis at initial examination. Both had perfusion lung scans that showed high probability for pulmonary embolism. Follow-up radionuclide venography and perfusion lung scanning was carried out on one patient after 6 days and on the other after 7 days. Both showed partial regression of abnormality in lung scan but entirely normal venogram. I am sure the authors can shed further light on this problem, which deserves systematic evaluation. I am confident that the eight false-normal lung scans will be found to have been done at least 24 hr following onset of the clinical problem, and I believe delay in performing venography probably accounts for many of the false normal results described in this paper (*1*) and in previous reports.

3. "Emission venograms were interpreted as abnormal if one of the following criteria were met: (a) venous occlusion with or without collaterals; (b) intraluminal defects in ileofemoral segment with stasis distal to the partially occluded segment." How many abnormal venograms met criteria (a) only, (b) only, or both? Venous occlusion may represent permanent residual of old thrombophlebitis. Since the criteria for final diagnosis of pulmonary embolism were primarily clinical, I wonder if any of the "false-normal" lung scans were actually correct with diagnosis inferred from venogram abnormality representing sequalae of previous disease.

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REFERENCE

1. MUNIR A, FLETCHER JW, PUR-SHAHRIARI AA, et al: Radionuclide venography and lung scanning: Concise communication. *J Nucl Med* 20: 291-293, 1979

Reply

In Table 1 of our article (*1*), perfusion studies with high probability of pulmonary embolus were considered positive, whereas normal nondiagnostic, or low probability perfusion lung scans were handled as negative. The note at the bottom of this table ("+ lung interpreted as low probability for pulmonary embolus") applies to negative lung scans in that column.

We agree with Dr. Wolfstein that pulmonary embolus is highly unlikely if the perfusion study is normal. None of the patients considered to have pulmonary embolus in this study had normal perfusion.

We emphasize the importance of follow-up studies in patients who have evidence of thromboembolism (*2*), and of a simultaneous repeat emission venogram. The latter increases the diagnostic accuracy of acute venous thrombosis, since it is invariably associated with evolutionary changes, whereas chronic venous disease without superimposed acute thrombi remains unchanged.

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REFERENCES

1. AHMAD M, FLETCHER JW, PUR-SHAHRIARI AA, et al: Radionuclide venography and lung scanning: Concise communication. *J Nucl Med* 20: 291-293, 1979
2. SASAHARA AA, BELKO JS, MCINTYRE KM: Problems in the diagnosis and management of pulmonary embolism. *Semin Nucl Med* 1: 122-131, 1971

Scintigraphic Findings in Angioimmunoblastic Lymphadenopathy

Angioimmunoblastic lymphadenopathy (AIL) is a lymphoproliferative syndrome first described by Lukes and Tindle in 1973 as immunoblastic lymphadenopathy (*1*). The syndrome is characterized by fevers, sweats, weight loss, rash, pruritus, lymphadenopathy, hepatosplenomegaly, and hypergammaglobulinemia. The clinical course is usually rapid and fatal (*2*). The lymph-node architecture is distorted by infiltration with immunoblasts and a peculiar proliferation of aborizing postcapillary venules (*4*). The disorder usually appears between the third and fifth decades and is slightly more common in males. Its initial clinical presentation often suggests malignant lymphoma, and histologically it resembles Hodgkin's disease (*1*). Radiographic findings in AIL had been reported (*2,5*), but its scintigraphic characteristics have not been described in detail. We discuss here the scintigraphic findings in two patients with AIL. The first case had a malignant course; the