

CT measurement of main pulmonary artery diameter

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Abstract. The aim of this study was to determine the upper limit of the normal main pulmonary artery diameter using a modern CT system. This was measured at the level of the pulmonary artery bifurcation in 100 normal subjects using unenhanced contiguous 10 mm CT slices viewed at fixed mediastinal window settings (400/20). These normal subjects were then compared with similar unenhanced 10 mm images from 12 patients with proven pulmonary arterial hypertension (mean pulmonary artery pressure > 20 mmHg). The main pulmonary artery diameter in normal subjects was 2.72 cm (SD=0.3). Main pulmonary artery diameter in patients with pulmonary arterial hypertension was significantly greater ($p < 0.01$) at 3.47 cm (SD=0.33). A pulmonary artery diameter of 3.32 cm (main pulmonary artery diameter + 2 SD) had a 58% sensitivity and 95% specificity for the presence of pulmonary arterial hypertension. It is concluded that, using unenhanced axial 10 mm CT sections, the upper limit of normal main pulmonary artery diameter is 3.32 cm. Pulmonary arterial hypertension should be considered in patients with values above this level.

Several studies in the late 1970s and early 1980s have measured the diameter of the central pulmonary arteries using axial CT [1, 2]. It has been shown that an increase in the diameter of the pulmonary arteries, in particular the main pulmonary artery, is a strong predictor of the presence of pulmonary hypertension [1]. Although these studies attempted to determine the normal range of main pulmonary artery diameter, either very small samples or non-standard window settings were used. In addition, intravenous contrast medium was administered to many of these patients in order to define better the pulmonary arteries. It is therefore difficult to apply these results to the unenhanced images obtained from modern CT equipment using conventional mediastinal window settings. A need was perceived for a value that would give a threshold above which further investigation for pulmonary hypertension would be indicated.

This study aimed to measure the normal diameter of the main pulmonary artery by CT in a large number of subjects without the use of intravenous contrast medium, using conventional mediastinal window settings. These values were then compared with those obtained from patients with pulmonary artery hypertension.

Materials and methods

All conventional thoracic studies performed over a 5 month period were evaluated. The normal

patient group consisted of 100 subjects (61 males, 39 females, age range 11–90 years). Patients were excluded if there was a history of: (1) cardiac or thoracic disease associated with an elevation in either pulmonary flow or pulmonary pressure; (2) mediastinal disease; (3) chest or mediastinal radiation therapy. Contiguous 10 mm slices were obtained using a Somatom Plus 4A CT machine (Siemens Medical Systems, Erlangen, Germany) and a 15 s breath-hold spiral technique (pitch 1.5, 0.75 s rotation time, 10 mm reconstruction interval). Intravenous contrast medium was not administered.

Images were subsequently reviewed on an independent workstation (21 inch monitor) at standardized mediastinal window settings (W:400/L:20).

The region of the ascending aorta and pulmonary artery was magnified to full screen size. The widest diameter perpendicular to the long axis of the main pulmonary artery was measured with computer callipers at the level of the pulmonary artery bifurcation (Figure 1). Two trained observers who reached a consensus on each measurement performed all measurements. 10% of the measurements were repeated to measure intraobserver variation and the results analysed using the "method comparison" statistical technique [3].

The above normal patient group was then compared with 12 patients (5 males, 7 females; age range 29–70 years) with established pulmonary arterial hypertension from right-heart catheterization studies (mean pulmonary artery pressure

Received 16 March 1998 and in revised form 12 June 1998, accepted 18 June 1998.

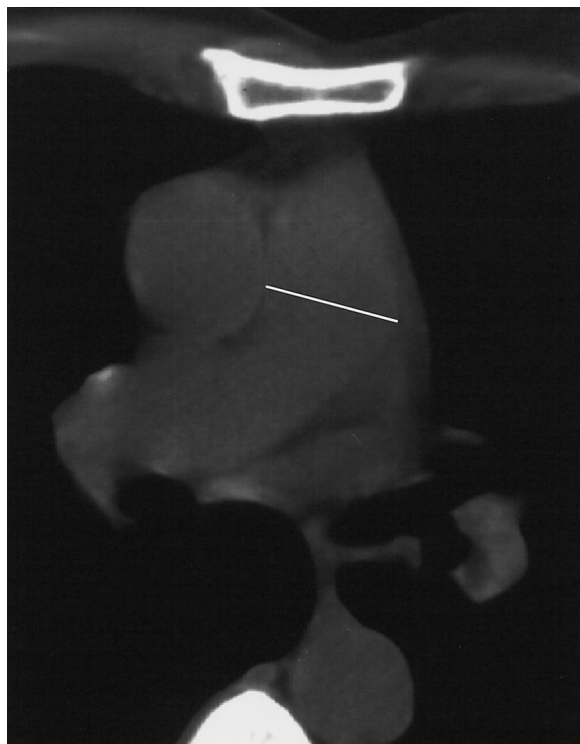


Figure 1. Representative image of main pulmonary artery and measurement point.

range 33–63 mmHg; mean 49 mmHg). In this group, 10 mm slices were obtained using a Somatom Plus CT System (single slice per breath-hold, 5 mm interslice gap, 1 s scan rotation). Intravenous contrast medium was not administered.

Results

Figure 1 shows a representative image demonstrating the point at which the main pulmonary artery was measured. Figure 2 summarises values for pulmonary artery diameter obtained in normal patients and those with pulmonary arterial hypertension.

Mean pulmonary diameter in patients with pulmonary arterial hypertension was significantly greater (two-tailed *t* test: $p < 0.01$) than in normal

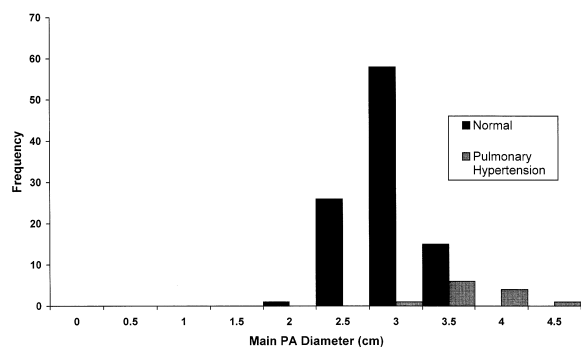


Figure 2. Main pulmonary artery diameter in normal and pulmonary hypertensive patients.

patients. Values for pulmonary artery diameter greater than 3.32 cm (mean normal pulmonary artery diameter + 2 SD) had a 95% specificity and a 58% sensitivity for the detection of pulmonary artery hypertension, assuming that the normal patients in this study did not have occult pulmonary artery hypertension.

There was close agreement in the 10% of patients whose measurements were repeated (mean difference = 0.02 cm; SD = 0.08; SE = 0.03). The 95% confidence limits of the intraobserver variation for measurement of the main pulmonary artery (mean \pm 2 SE) were -0.04 cm to 0.08 cm. This range includes zero and there is therefore no measurement bias.

As shown in Figure 3 there was no significant correlation between pulmonary artery diameter and age.

Discussion

Previous studies have attempted to measure the diameter of the normal main pulmonary artery using axial CT [1, 2]. The largest study measured the diameter of the main pulmonary artery in 26 healthy control subjects, obtaining a mean value of 2.42 cm with a standard deviation of 0.22 cm [1]. The diameter of the central pulmonary artery measured by CT in 32 age matched patients was then correlated with pulmonary artery pressure measurements obtained by cardiac catheterization. In these patients, a diameter of the main pulmonary artery above 2.86 cm (control mean value + 2 SD) predicted the presence of pulmonary hypertension (defined as mean PA pressure > 18 mmHg) with a sensitivity of 69% and a specificity of 100%. The diameters of the left and right pulmonary arteries were also measured but proved to be poorer predictors of the presence of pulmonary hypertension. It was therefore concluded that the main pulmonary artery diameter measured by CT was a valuable non-invasive method of predicting the presence of pulmonary artery hypertension. Despite those findings, there are several problems in applying their results to the conventional CT images produced in most departments. Firstly, pulmonary artery

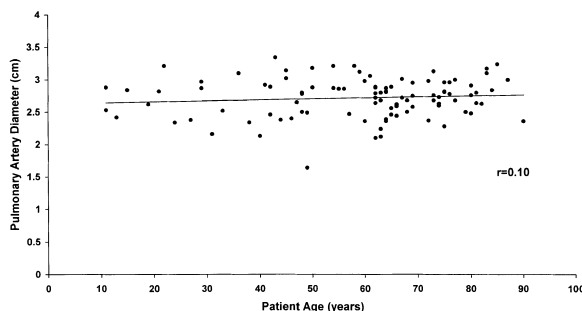


Figure 3. Relationship of main pulmonary artery diameter and patient age.

diameter was measured using non-standard window widths by a computer program using density profiles. CT window width has a considerable influence on anatomical measurements [4]. Kuriyama et al conceded that their arterial diameter measurements using density profiling techniques are likely to differ from measurements made using more conventional mediastinal window settings [1]. In addition, this paper did not state the proportion of patients who received intravenous contrast medium and in what proportion of these studies the main pulmonary artery was reliably identified.

Gunthamer et al [2] measured the diameter of the main pulmonary artery directly from contrast enhanced CT images, obtaining a mean pulmonary artery diameter of 2.80 cm. However, their study was performed on a very small sample (10 subjects) and window settings were not stated. The main pulmonary artery diameter was not measured in other studies which measured components of the pulmonary arterial tree [5, 6].

The upper limit of normal of 3.32 cm for the main pulmonary artery diameter in the present study is considerably greater than Kuriyama et al's value of 2.86 cm [1]. The major reason for the discrepancy is likely to be the different window settings used in the two studies (see above). In addition, contrast medium was used to visualize the pulmonary artery in many of Kuriyama et al's patients, in which case the measured diameter was that of the pulmonary artery lumen whilst the external diameter of the artery was measured in our study. Another possible reason for this discrepancy may be due to interracial differences—Kuriyama et al's patients were predominantly of Japanese origin whilst our patients were predominantly of Anglo-Saxon origin.

In addition, we have shown that measurement of pulmonary artery diameter is extremely reproducible with a standard deviation for the difference between 2 measurements of less than 0.08 cm and a mean difference of only 0.02 cm.

The separation of pulmonary artery diameter between groups with and without pulmonary hypertension shows a moderate degree of overlap. This is probably due in part to the relatively low values of pulmonary hypertension for some of the patients who underwent cardiac catheterization. In addition, the actual values of pulmonary arterial pressure in the patients in the normal group are unknown. Ethically, this information would be difficult to obtain as this group of patients are unlikely to have occult pulmonary artery hypertension.

This study is the first to attempt to define the relationship between main pulmonary artery diameter and the age and sex of the patient. No significant correlation was found between pulmonary artery diameter and age (Figure 3). However, this study does show that mean PA diameter is greater in men than women (males, 2.77 cm; females, 2.64 cm). Although this difference is statistically significant (two-tailed *t* test: $p < 0.05$), a difference of only 0.13 cm is probably of little clinical importance. It is hypothesized that this difference may be due to male subjects tending to have larger overall dimensions than female patients, thus their pulmonary arteries also tend to be slightly larger. This hypothesis could be tested by relating pulmonary artery diameter to patient dimensions, for example body surface area.

Conclusion

We conclude that when viewing unenhanced axial 10 mm sections through the mediastinum at standardized mediastinal window settings, the upper limit of normal main pulmonary artery diameter is 3.32 cm. Values above this level, although relatively insensitive, are highly specific for the presence of pulmonary arterial hypertension.

Acknowledgments

We are grateful for the assistance of Dr P M Kemp, Fellow of the Royal Society of Statisticians for his help with analysis of the data and also to the radiographers of the Addenbrooke's CT Unit. We are also grateful for the assistance of Professor A K Dixon for his assistance in the preparation of this manuscript.

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