Measurement of bronchodilatation using a superfine fibreoptic bronchoscope

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Summary
In this study, we report the development and accuracy of a direct technique to measure airway calibre using a superfine fibreoptic bronchoscope. Ten mongrel dogs were anaesthetized with pentobarbitone and the trachea intubated with a tracheal tube; the small lumen of the tube allowed passage of a superfine fibreoptic bronchoscope (od 2.2 mm). Bronchial cross-sectional area and airway pressure were recorded continuously and dynamic pulmonary compliance and airway resistance calculated. The dogs were allocated to one of two groups. In the first group (six dogs), bronchoconstriction was induced with histamine 10 μg kg⁻¹ i.v. and 500 μg kg⁻¹ h⁻¹ c.i.v. Thirty minutes later, adrenaline 0–0.4 mg kg⁻¹ was given i.v. Bronchial cross-sectional area, dynamic pulmonary compliance and airway resistance were assessed simultaneously. In the second group, 0.9% saline was given 30 min after placement of the superfine fibreoptic bronchoscope and 10 min later atropine 0.1 μg kg⁻¹ was administered. In the first group, histamine decreased mean percentage bronchial cross-sectional area by 49.2 (sd 11.5) %, reduced dynamic pulmonary compliance from 32.1 (12.6) to 22.3 (5.2) ml cm H₂O⁻¹ and increased airway resistance from 39.1 (11.6) to 57.2 (10.2) cm H₂O litre⁻¹ s⁻¹. Adrenaline produced a dose-dependent increase in percentage bronchial cross-sectional area and dynamic pulmonary compliance to 119.4 (31.3) % and 27.4 (5.5) ml cm H₂O⁻¹, respectively, and a decrease in airway resistance to 43.9 (7.2) cm H₂O litre⁻¹ s⁻¹. There were significant correlations between percentage bronchial cross-sectional area and dynamic pulmonary compliance (r=0.720, P<0.0001) and airway resistance (r=0.727, P<0.0001). Atropine 0.1 mg kg⁻¹ increased basal bronchial cross-sectional area to 137.5 (16.9) %. These data indicate that adrenaline reversed histamine- and pentobarbitone-induced bronchoconstriction. (Br. J. Anaesth. 1997; 78: 583–585).

Key words

Airway calibre is influenced by several factors, including smooth muscle tone, oedema of the airway wall and airway secretory activity. Airway calibre is normally assessed indirectly by measuring airway resistance or compliance, and these can be influenced strongly by airway secretions. Moreover, several articles have noted the relative insensitivity of indirect measurements of airway calibre. Brown and colleagues developed a technique for direct measurement of airway calibre using high-resolution computed tomography and showed that changes in airway calibre were not always accompanied by changes in total pulmonary resistance. While their direct method appeared more specific than conventional indirect measures of airway calibre, the system is too large to use conveniently as an airway monitor in the operating theatre or in the intensive care unit. In this study, we report the development of a new portable direct method to quantify bronchial calibre using a superfine fibreoptic bronchoscope.

Methods and results
After obtaining approval from our Animal Care Committee, 10 mongrel dogs (8–12 kg) were anaesthetized with pentobarbitone 30 mg kg⁻¹ i.v. and paralysed with pancuronium 200 μg kg⁻¹ h⁻¹ d.i.v. The trachea was intubated with a special tracheal tube (internal diameter 7.0 mm; Fuji system, Tokyo) with a small lumen into which a superfine fibreoptic bronchoscope (outer diameter 2.2 mm; OES Angiofiberscope AF type 22A, Olympus, Tokyo, Japan) could be inserted. With the tip of the fibrescope located between the second and third bifurcation of the right lung, bronchial cross-sectional area was monitored continuously. In addition, a pulmonary arterial catheter was inserted via the femoral vein to allow infusion of lactate Ringer’s solution at 4 ml kg⁻¹ h⁻¹ and for drug administration. Systemic arterial pressure was monitored directly via the femoral artery.

AIRWAY ANALYSIS
The lungs were ventilated with a respirator

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Airway pressure was recorded continuously to calculate dynamic pulmonary compliance and airway resistance. Dynamic pulmonary compliance and airway resistance are reported as the mean value of three consecutive breaths. Bronchial cross-sectional area (as seen by the bronchoscope) at the second–third bifurcation was monitored continuously. The bronchial cross-sectional area image on the monitor was printed via a videoprinter (Videoprinter VY-170, Hitachi, Tokyo, Japan) and measured using image analysis software (NIH image program which is well established and used widely; written by Wayne Rasband at the US National Institutes of Health and available from the Internet by anonymous ftp from zippy. nimh. nih. gov or on floppy disk from NTIS, 5285 Port Royal Rd., Springfield, VA 22161, part number PB93–504868).

The dogs were allocated to one of two groups: adrenaline–histamine group (n = 6) and atropine group (n = 4). In the adrenaline–histamine group, bronchoconstriction was induced with histamine 10 μg kg⁻¹ i.v. followed by infusion of 500 μg kg⁻¹ h⁻¹ via the pulmonary arterial catheter. Systolic arterial pressure was maintained greater than 80 mm Hg with fluid (lactate Ringer’s solution 50 ml kg⁻¹) and with continuous infusion of phenylephrine 0.5–2.0 μg kg⁻¹ min⁻¹, the rate being dependent on systolic arterial pressure. Thirty minutes later, when stable bronchoconstriction was achieved, adrenaline was given i.v.: 0 (0.9% saline), 0.05, 0.1, 0.2 and 0.4 μg kg⁻¹. The first measurement of dynamic pulmonary compliance and airway resistance was performed before insertion of the fibrescope. Bronchial cross-sectional area, dynamic pulmonary compliance and airway resistance were measured before and 30 min after the start of infusion of histamine and 1 min after each dose of adrenaline. At least 5 min elapsed between each dose of adrenaline. Measured bronchial cross-sectional area, dynamic pulmonary compliance and airway resistance were also expressed as a ratio of basal values (percentage bronchial cross-sectional area, percentage dynamic pulmonary compliance and percentage airway resistance, respectively). In the atropine group, bronchoconstriction was not induced. Thirty minutes after fixation of the bronchoscope, 0.9% saline and 10 min later atropine 0.1 mg kg⁻¹ were administered i.v. Only bronchial cross-sectional area was measured before and 5 min after saline and atropine to determine if pentobarbitone anaesthesia reduced bronchial calibre, as seen with thiopentone anaesthesia.¹⁵

DATA ANALYSIS

All data are expressed as mean (SD). The correlations between percentage bronchial cross-sectional area and percentage dynamic pulmonary compliance and between percentage bronchial cross-sectional area and percentage airway resistance were calculated by computer assisted curve fitting (Graphpad-Prism). Data were analysed by repeated-measures ANOVA followed by the Scheffe F test. P < 0.05 was considered significant.

In the adrenaline–histamine group, fibrescope insertion produced no significant change in airway resistance (40.0 (12.4) to 39.1 (11.6) cm H₂O litre⁻¹s⁻¹) or dynamic pulmonary compliance (32.0 (12.5) to 32.1 (12.6) cm H₂O⁻¹). Histamine decreased percentage bronchial cross-sectional area by 49.2 (11.5)%; reduced dynamic pulmonary compliance from 32.1 (12.6) to 22.3 (5.2) ml cm H₂O⁻¹ (percentage dynamic pulmonary compliance by 25.2 (7.8)% and increased airway resistance from 39.1 (11.6) to 57.2 (10.2) cm H₂O litre⁻¹s⁻¹ (percentage airway resistance to 153.4 (12.7)%). Adrenaline produced a dose-dependent increase in percentage bronchial cross-sectional area and percentage dynamic pulmonary compliance and a decrease in percentage airway resistance (fig. 1A). There was a significant correlation (fig. 1B) between percentage bronchial cross-sectional area and percentage pulmonary compliance (r = 0.720, P < 0.0001) and percentage airway resistance (r = 0.727, P < 0.0001).

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**Figure 1** A: Bronchoconstriction induced by infusion of histamine 10 μg kg⁻¹ i.v. and 500 μg kg⁻¹ h⁻¹. Changes in percentage bronchial cross-sectional area, percentage dynamic pulmonary compliance and percentage airway resistance. Data are mean, SD (n = 6). *P < 0.05, **P < 0.01 compared with adrenaline 0 μg kg⁻¹. B: Correlation between percentage bronchial cross-sectional area and percentage dynamic pulmonary compliance (r = 0.720, P < 0.0001) and percentage airway resistance (r = 0.727, P < 0.0001).
dynamic pulmonary compliance ($r = 0.720$, $P < 0.0001$) and percentage bronchial cross-sectional area and percentage airway resistance ($r = 0.727$, $P < 0.0001$). When these correlations were analysed separately for each subject, the correlation was improved ($r = 0.889$ (0.021) and $r = 0.906$ (0.044), respectively). In the atropine group, atropine 0.1 mg kg$^{-1}$ produced a significant increase in basal bronchial cross-sectional area to 137.5 (13.8) % ($P < 0.05$) compared with bronchial cross-sectional area after administration of 0.9% saline (100.7 (9.8) %).

Comment

In this study we have reported a new direct method for assessment of airway calibre using a superfine fibreoptic bronchoscope and compared this with conventional indirect measures of dynamic pulmonary compliance and airway resistance. We reported a good correlation between percentage bronchial cross-sectional area, percentage dynamic pulmonary compliance and percentage airway resistance and suggest that our method provided simple, accurate and direct measurement of airway calibre. Calculation of dynamic pulmonary compliance and airway resistance requires airway pressure and pressure gradient measurements, which are dependent on airway smooth muscle tone, presence of oedema, secretion and airflow rate and pattern. Histamine-induced bronchoconstriction, used in this study, produces not only airway smooth muscle contraction and oedema but also an increase in airway secretion which would strongly affect airway pressure measurements but have little effect on airway calibre. Therefore, dynamic pulmonary compliance and airway resistance do not accurately reflect airway calibre.

In support of this notion Brown and colleagues, using high resolution computed tomography, reported that changes in airway calibre did not always follow changes in total pulmonary resistance. Our data also suggested that direct assessment of airway calibre using a superfine fibreoptic bronchoscope was more sensitive than dynamic pulmonary compliance and airway resistance. In histamine pre-constricted airways, adrenaline produced greater bronchodilatation than that observed before histamine administration when assessing percentage bronchial cross-sectional area, yet percentage dynamic pulmonary compliance and percentage airway resistance did not completely return to pre-histamine values. These finding were not unexpected. As described above, infusion of histamine increases not only airway smooth muscle tone but also airway secretion. Even if adrenaline completely reversed smooth muscle contraction, airway secretions cannot be excluded. Therefore, dynamic pulmonary compliance and airway resistance would not return fully to basal as airway secretions were not aspirated during the experiment. In addition, our data suggest that pentobarbitone anaesthesia may increase vagal tone to reduce airway calibre as atropine increased basal bronchial cross-sectional area to approximately 140%. Similar data have been reported by Brown and colleagues for thiopentone where atropine 0.2 mg kg$^{-1}$ caused significant airway dilatation (151 (25) %).

In this study, phenylephrine (an $\alpha$-agonist) was given i.v. at 0.5–2.0 mg kg$^{-1}$ min$^{-1}$ to maintain systolic arterial pressure greater than 80 mm Hg. When the effect of phenylephrine on histamine-induced bronchoconstriction in dogs ($n = 6$) was studied previously, we found that phenylephrine 100 $\mu$g kg$^{-1}$ significantly increased histamine bronchoconstriction while phenylephrine 1.0 and 10 $\mu$g kg$^{-1}$ did not (unpublished data). Therefore, the dose of phenylephrine we used did not significantly affect histamine-induced bronchoconstriction.

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References