Should computed tomography of the chest be recommended in the medical certification of professional divers?

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Chest CT should not be used in the assessment of fitness to dive

Toklu *et al*¹ have raised the question of whether routine high resolution computed tomographic (CT) scanning of the chest should form part of the initial diving medical examination for occupational divers. The authors make this proposition in discussing their series of three divers in which pulmonary abnormalities were discovered on high resolution CT scan after occupational diving incidents. One case involved a bulla, the second multiple air cysts, and the last a subpleural bleb. The authors assume that the initial mechanism of injury in each case was pulmonary barotrauma associated with the lesions revealed.

One could argue whether the second and third cases may have involved arterialisation of venous bubbles rather than pulmonary barotrauma, but any uncertainty does not invalidate consideration of the authors' contentions. It is widely agreed that lung cysts, bullae, and blebs may all predispose to pulmonary barotrauma, and most authorities recommend disqualification from diving if such lesions are found.²⁻⁴ This report adds to others in which CT scans have revealed pulmonary abnormalities in diving accident victims where chest radiographs did not.^{5,6} I have also managed a similar case of apparently undeserved arterial gas embolism after years of uneventful diving in a healthy man with a normal chest radiograph. Subpleural blebs were discovered on incidental CT scan several years later.

Pulmonary barotrauma in divers often occurs in the provocative setting of uncontrolled ascent, with rapid gas expansion and the potential for high transthoracic pressures.^{6,7} It is estimated that a normal lung will rupture if a transtracheal pressure of 75–80 mm Hg is exceeded, and pulmonary structural predisposition is not needed to explain such incidents.^{8,9} Prevention of such cases should focus on psychological suitability for underwater work, training, equipment reliability, and operational diving practice. Where barotrauma initially appears "undeserved", as in the cases

of Toklu *et al*, however, it is particularly tempting to search for predisposing pathology and assume cause and effect if lesions are discovered. Caution is necessary with such an approach as it tends to produce a self supporting literature. To better estimate risk would require at least several major case series from which the incidence of the purported predisposing factor(s) could be reliably estimated and compared with the incidence in suitable control populations. Herein lies a major limitation; no such large series exist in the diving medicine literature, and rapidly evolving medical imaging technology has not been matched with publication of the findings on control populations of healthy normals let alone divers specifically.

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More structural abnormalities are revealed with higher resolution imaging,¹⁰ and this will create a problem with the increasing use of digital radiology as well as with increased use of CT scanning: more and more potential and practising divers will be discovered to have cysts, bullae, or blebs, in some cases completely incidentally. Anecdotally, radiologists in my institution do not routinely report on small blebs on CT scans as they are so common as to be considered normal findings in the patient population seen by a major hospital radiology department. The problem will be worst for older divers. Abnormalities on plain radiograph increase with age and with smoking: in 497 shipyard workers screened with plain radiography, bullae were revealed in 10.3% of smokers and 1.3% of those who had never smoked.¹¹ These rates would almost certainly have been much higher if CT scans had been undertaken. It is clear that widespread high resolution imaging of divers would disqualify

many who would never have an accident, were current recommendations on fitness to dive followed. It is not at all clear whether this would bring about any reduction in pulmonary barotrauma incidents. Further, as Gorman¹² has recently pointed out, the entire principle of using exclusionary criteria in occupational medical examinations for divers is fundamentally at odds with both the principles of individual risk assessment and the various forms of human rights and disabled persons legislation that require access to employment unless irremediable and excessive risk can be proven.

Recommending exclusion of divers with lung cysts, bullae, or blebs has been based on mechanistic speculation and the lack of these features in healthy young people compared with the case reports and small case series in which such features have been detected at post mortem, by radiography and now CT scan in divers who have suffered arterial gas embolism, pneumothorax, or pneumomediastinum.⁶⁻⁸ Although lung bullae and cysts continue to be listed as contraindications to diving fitness in the well researched 2003 British Thoracic Society guidelines,² one of the authors of that report has previously argued that cysts and bullae may not predispose to barotrauma on the basis that ventilated spaces should empty in all but the most extreme ascents, and non-ventilated spaces should not expand to exceed their starting volume.⁹ Further, it may not be valid to consider all of these abnormalities together. In the field of aviation medicine, cysts and bullae of presumed degenerative, infective or congenital origin may be individually considered depending on the nature of the proposed aviation exposure and the behaviour of such lesions as shown by imaging during ventilation or even hypobaric chamber exposure. Small subpleural blebs are commonly found in patients with spontaneous pneumothorax, and these are considered a separate risk category from those with intrapulmonary lesions.¹³

It is interesting to note that the literature on spontaneous pneumothorax also includes argument as to whether subpleural blebs do or do not predict increased risk, at least of recurrence of pneumothorax.¹⁴ In divers it does seem likely that there is some association, but it may well be that blebs and bullae are markers for at risk lungs rather than the actual site of lung rupture. After more provocative ascents, blebs may be the result rather than the cause of the incident. Without the availability of cases with imaging both before and after the incident, this is difficult to confirm.

Current expert opinion seems to be that a major underlying predisposing factor for lung barotrauma is likely to be scarring, fibrosis, or decreased tissue compliance, especially where this is non-homogeneous. This is thought to predispose to development of shear forces as the lung expands, risking tears occurring in the bronchiolar lining.⁷⁻⁹ It is also reasonable to hypothesise that there may be variability in the tensile strength of lung tissue across the population, and within any one lung this factor may be relatively homogeneous or variable. The variability of these characteristics of compliance homogeneity and tensile strength together could result in a wide range of susceptibility or resistance to pulmonary barotrauma, even in apparently healthy people. This proposal would also be consistent with findings in cases of primary spontaneous pneumothorax where half of otherwise healthy sufferers have no identified blebs or other structural predisposing factors.¹⁵ In divers having CT scans, Denison⁹ has reported on cases of pneumomediastinum developing during the deep breathing involved in the scan. It can even be speculated that microrupture of the lung is a relatively common and perhaps even "normal" event, which usually has no clinical consequences if the result is at worst a small air leak into the local interstitial tissues, which self seals and heals asymptotically. If decompression were to occur during such a time, however, the expansion of air in the lungs might very easily produce a significant temporary air leak even with a relatively controlled ascent rate. If these theories are correct, functional compliance testing and imaging for fibrosis rather than for abnormal air spaces may prove more predictive of barotrauma risk.

Toklu *et al* accept that CT scanning at all examinations would be impractical and suggest restriction to the initial medical examination only, especially in those with a history of smoking or lung infection. It seems apparent that even

this cannot be supported in the current environment. Given the relative rarity of pulmonary barotrauma and the frequency with which we could expect to find abnormality, screening CT would not only be unjustifiably costly in financial terms but also in terms of potential divers unnecessarily excluded from an occupation or recreation to which they might be well suited.

Questions about the true association of cysts, bullae, and blebs with risk for divers will not go away, however. Rather, they will present an increasingly common dilemma for medical assessors of both occupational and recreational divers, given trends towards individualised risk assessment and continuing improvements in technology. More diver treatment facilities need to build on the reports of Tetzlaff *et al*¹⁵ comparing findings of thoracic CT scans from pulmonary barotrauma cases with those from divers presenting for other reasons. Centralised registries of diving accident data would enable compilation of sufficiently large case numbers to gain a better idea of any associations. It is hoped that important denominator information will also become available if sufficient medical examiners respond to Watt's call for submission of medical examination reports to his pulmonary risk evaluation audit.² Relatively rare conditions such as pulmonary barotrauma require very large data sets to indicate any significant associations, and the greatest potential probably lies in the hope that more countries adopt a centralised system of occupational diver medical examination assessment and data management such as that established in New Zealand. Until more information is available, it will be important for those interpreting high resolution imaging findings not to jump to the conclusion that any lesion detected should automatically indicate unfitness to dive.

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REFERENCES

- 1 Toklu AS, Kiyan E, Aktas S, *et al*. Should computed chest tomography be recommended in the medical certification of professional divers? A report of three cases with pulmonary air cysts. *Occup Environ Med* 2003;**60**:606-8.
- 2 Godden D, Currie G, Denison D, *et al*. British Thoracic Society guidelines on respiratory aspects of fitness for diving. *Thorax* 2003;**58**:3-13.
- 3 Bove AA. Fitness to dive. In: Brubakk AO, Neuman TS, eds. *Bennett and Elliot's physiology and medicine of diving*. 5th ed. Philadelphia: Saunders, 2003:700-17.
- 4 Walker R. Medical standards for recreational divers. In: Edmonds C, Lowry C, Pennefather J, *et al*, eds. *Diving and subaquatic medicine*, 4th ed. London: Arnold, 2002:533-51.
- 5 Tetzlaff K, Reuter M, Leprow B, *et al*. Risk factors for pulmonary barotrauma in divers. *Chest* 1997;**112**:654-9.
- 6 Russi EW. Diving and the risk of barotrauma. *Thorax* 1998;**53**(suppl 2):S20-4.
- 7 Neuman TS. Arterial gas embolism and pulmonary barotrauma. In: Brubakk AO, Neuman TS, eds. *Bennett and Elliot's physiology and medicine of diving*. 5th ed. Philadelphia: Saunders, 2003:557-77.
- 8 Walker R. Pulmonary barotrauma. In: Edmonds C, Lowry C, Pennefather J, *et al*, eds. *Diving and subaquatic medicine*, 4th ed. London: Arnold, 2002:55-71.
- 9 Denison DM. Mechanics of pulmonary barotrauma. In: Elliott D, ed. *Medical assessment of fitness to dive*. Ewell: Biomedical Seminars, 1995:112-13.
- 10 Mitlehner W, Friedrich M, Dischmann W. Value of computer tomography in the detection of bullae and blebs in patients with spontaneous pneumothorax. *Respiration* 1992;**59**:221-7.
- 11 Kilburn KH, Warshaw RH, Thornton JC. Do radiographic criteria for emphysema predict physiologic impairment? *Chest* 1995;**107**:1225-31.
- 12 Gorman DF. From police to health adviser: the evolution of modern occupational health surveillance. *SPUMS J* 2003;**33**:134-9.
- 13 Gray GW, Pickard JS. Respiratory diseases: aeromedical implications. In: DeHart RL, Davis JR, eds. *Fundamentals of aerospace medicine*, 3rd ed. Philadelphia: Lippincott Williams & Wilkins, 2002:323-32.
- 14 Schramel FMNH, Zanen P. Blebs and/or bullae are of no importance and have no predictive value for recurrences in patients with primary spontaneous pneumothorax. *Chest* 2001;**119**:1976-7.
- 15 Wait MA, Estrera A. Changing clinical spectrum of spontaneous pneumothorax. *Am J Surg* 1992;**164**:528-31.