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The therapeutic use of air under hyperbaric pressure

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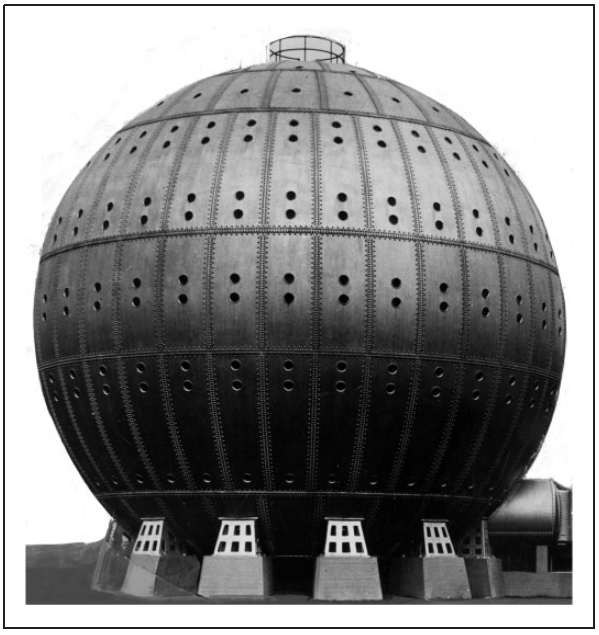

Cover photo. The 'Timken Tank' at the Cunningham Sanitarium, Cleveland, Ohio, USA, December 1928. The 64-foot diameter, five-storey steel structure weighed 1000 tons, and the interior was pressurised to two atmospheres with compressed air. Construction of the sanitarium cost US$1,000,000 and was financed by Henry Heinzelman (H.H.) Timken, chairman of the board of the Timken Roller Bearing Company.
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> The use of atmospheric air, under different degrees of barometric pressure, in the treatment of disease, is one of the most important advances of modern medicine.
>
> C Theodore Williams, April 1885[1]

In 1664, two decades after Evangelista Torricelli devised the mercury barometer,[2] and more than a century before the discovery of oxygen,[3] Nathaniel Henshaw published a short treatise describing a sealed 'domicilium, or air chamber' in which the atmospheric pressure could be 'rarefied or condensed' for 'the better preservation of health and cure of diseases'.[4] Air was manually forced into or out of the domicilium using a large pair of organ bellows. It was recommended that the chamber 'be well charged with air' in the treatment of acute diseases, and the barometric pressure reduced for chronic conditions. Henshaw also suggested the domicilium might serve: 'as a good expedient to help digestion… to facilitate breathing and expectoration, and… for the prevention of most affections of the lungs'. While a second edition of his book was printed in 1677 by order of the Council of the Royal Society of London,[5] and a reviewer noted the 'ingenuity and usefulness of the discourse therein contained',[6] there is no evidence that the idea was put to practical use, and it would be more than 150 years before interest in the subject was renewed.

During the early 1830s in France, Victor Junod, Émile Tabarié and Charles Pravaz were among the first to construct 'les bains d'air comprimé' ('compressed air baths') and formally assess the therapeutic effects of exposure to modest hyperbaric pressures.[7–10] Utilising a spherical copper chamber 1.4 m in diameter and a steam-powered air pump, Junod observed: 'when we increase by one half the natural pressure of the atmosphere… the membrane of the eardrum, pushed back towards the inner ear, becomes the seat of a rather unpleasant pressure. However, this sensation disappears as equilibrium is re-established. The respiratory movements go on with new ease, the capacity of the lungs for air seems to increase… after 15 minutes, one

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feels an agreeable warmth within the thorax… functions of the brain are activated, the imagination is lively, thoughts have a peculiar charm…. this increase of innervation acts also upon the muscular system; movements are easier and more assured.'[7,10]

Larger hyperbaric chambers were constructed from wrought iron, and from the exterior, resembled the boiler of a steam engine. Thick plate-glass portholes were incorporated in the walls, and their interiors furnished with 'chairs and tables, a water bottle and glasses to meet the thirst and uncomfortable throat symptoms, which often accompany increase in pressure'.[1]

Initially trialled for a range of pulmonary conditions, including asthma, chronic bronchitis and tuberculosis, the use of air pressurised up to two atmospheres quickly 'exceeded in success, the anticipations formed of it'.[11] The range of suggested indications rapidly expanded to include a diverse array of medical conditions, as well as various 'nervous and metal affections'.[12] By the late 19th century, compressed air baths were 'greatly in vogue' in mainland Europe,[1] where there were no fewer than 50 hospitals, sanatoria and specialist 'aerotherapeutic institutes' offering treatments; a handful of chambers were also in use in England, Scandinavia and the United States.[1,11,12]

The detailed physiological research conducted by Paul Bert at the Sorbonne during the 1870s did much to improve the scientific understanding and practical application of hyperbaric therapy.[10] This extended to the field of anaesthesia, and in November 1878 he read a paper before the French Academy of Sciences concerning the prolonged use of nitrous oxide.[13] Bert noted: 'the fact that nitrous oxide must be administered pure indicates that in order to be absorbed by the organism in sufficient quantity, the tension of the gas must be equal to 1 atmosphere…. To achieve this at normal pressure, the gas must be in the proportion of 100%. But let us suppose that the patient is placed in an apparatus where the pressure can be increased to 2 atmospheres; then one could submit him to the desired tension by making him inhale a mixture of 50% nitrous oxide with 50% air. Thus, one could achieve anaesthesia while maintaining the normal quantity of oxygen in the blood.'[13,14]

Within a year, Charles Labbé and Jules-Émile Péan had successfully performed 17 operations in Parisian aerotherapeutic institutions using Bert's method.[14] Shortly after, Joseph Fontaine, director of the medico-pneumatic establishment on the Rue de Châteaudun,[15] devised a mobile compressed air operating chamber. Patients received a mixture of nitrous oxide and oxygen, and the pressure in the chamber was manually raised using a handled pump.[14] Fontaine's hyperbaric 'car' was taken to hospitals all over Paris,[16] and in 1883 Bert reflected that this technique for nitrous oxide anaesthesia 'as nearly as possible approaches perfection'.[14,17]

Bert also correctly deduced that intra- and extravascular nitrogen bubbles were responsible for 'caisson disease'[18] (also known as 'the bends' or 'decompression sickness'),[19] which had become a significant cause of morbidity and mortality among those engaged in civil engineering in wet soils. In 1839 Jacques Triger was the first to use a compressed air 'caisson' (French, 'box') to bore a mine shaft through waterlogged silt in the Loire Valley.[20] The caisson comprised an open-ended iron cylinder, 1.5 m in diameter, which was driven through the full thickness of the saturated strata with a ram. An airlock (permitting entrance and egress of workers) was then fitted at the top, and the interior pressurised to three atmospheres using compressed air. This forced water out of the caisson, allowing labourers to excavate dry silt from the base, and expose the underlying coal seam. The high ambient pressure provided no impediment to working inside the caisson, but Triger recorded that 'two men after passing 7 consecutive hours in compressed air, experienced rather keen pain in their joints, half an hour after leaving the shaft'.[10,21]

Pressurised caissons were subsequently utilised to sink bridge foundations through the soft sediment overlying some river beds. As the use of this technology increased, the clinical signs and symptoms of decompression sickness were increasingly recognised. During the sinking of the second caisson for the Brooklyn Bridge in 1872, Andrew Smith, surgeon to the New York Bridge Company reported 110 cases of decompression sickness, of which three proved fatal.[18] While Smith postulated that the most frequent cause of caisson disease was 'too rapid locking out' and conceptualised a chamber for therapeutic recompression of those affected, it would be 1889 before Ernest Moir installed the first such facility, for workers tunnelling beneath the River Hudson.[22] Moir's 'medical air lock' was erected near the top of the shaft, and 'when a man was overcome or paralyzed… they were carried into the compartment and the air pressure raised… with immediate improvement'.[22] The pressure was then lowered at a very slow rate 'and even in severe cases the men went away quite cured'.[22]

In September 1918, Orval Cunningham, chief of anesthesia at the University of Kansas Hospital began treating moribund victims of the 'Spanish' influenza pandemic in a hyperbaric chamber borrowed from a local bridge building company.[23] Those 'not too far beyond the brink, in a matter of minutes were brought back to a normal colour'.[23] At the end of the pandemic Cunningham filed a patent for a hyperbaric chamber of his own design, in which patients could be 'effectively treated for certain diseases'.[24] These included diabetes,

osteoarthritis, pernicious anaemia, syphilis and cancer, which Cunningham theorised were caused by 'anaerobic bacteria', and could be 'cured by the use of compressed air'.[25] Despite fierce criticism from the American Medical Association's Bureau of Investigation, who stated that his claims were 'tinctured much more strongly with economics than with scientific medicine',[26] Cunningham went on to open a sanitarium incorporating the world's largest hyperbaric chamber in Cleveland, Ohio in 1928.[27] Use of the chamber was abandoned in 1936 and it was scrapped six years later as part of the American war effort.[28]

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References

1. Williams CT. Lectures on the compressed air bath and its uses in the treatment of disease. *BMJ* 1885; 1: 769–772.
2. Loria G and Vassura G (eds). [*Works by Evangelista Torricelli*], Volume 3. Faenza: G. Montanari, 1919.
3. Featherstone PJ and Ball CM. Early use of oxygen outside the operating theatre. *Anaesth Intensive Care* 2019; 47: 408–410.
4. Henshaw N. *Aero-chalinos, or, A register for the air for the better preservation of health and cure of diseases, after a new method*. Dublin: Samuel Dancer, 1664.
5. Henshaw N. *Aero-chalinos, or, A register for the air for the better preservation of health and cure of diseases, after a new method*, 2nd edn. London: Benj. Tooke, 1677.
6. An account of some books. *Philos Trans R Soc Lond* 1677; 12: 833–838.
7. Junod VT. *[Physiological and therapeutic researches on the effects of compression and rarefaction of the air, both on the body and on isolated limbs]*. Paris: Librairie de Deville Cavellin, 1834.
8. Tabarié É. [Researches on the effects of variations in atmospheric pressure at the surface of the body]. *C R Hebd Séances Acad Sci* 1838; 6: 896–897.
9. Pravaz C. Report on the application of the compressed air bath to the treatment of tuberculous diseases, capillary haemorrhages and catarrhal deafness. *Bull Acad Natl Med* 1837/1838; 2: 985–996.
10. Bert P. *Barometric Pressure. Translated by MA Hitchcock and FA Hitchcock*. Columbus: College Book Company, 1943.
11. Simpson A. *Compressed Air as a Therapeutic Agent in the Treatment of Consumption, Asthma, Chronic Bronchitis and Other Diseases*. Edinburgh: Sutherland and Knox, 1857.
12. Corning J. The use of compressed air in conjunction with medicinal solutions in the treatment of nervous and mental affections. *Med Rec* 1891; 40: 225–232.
13. Bert P. [On the possibility of obtaining prolonged anaesthesia with nitrous oxide and upon the harmlessness of that anaesthetic]. *C R Hebd Séances Acad Sci* 1878; 87: 728–730.
14. Duncum BM. *The development of inhalation anaesthesia*. London: Royal Society of Medicine Press, 1994.
15. Fontaine JA. *Physiological effects and therapeutic applications of compressed air*. Paris: Germer-Bailliere, 1877.
16. Allinson TR. An anaesthetic car. *BMJ* 1881; 2: 110.
17. Bert P. [Prolonged anaesthesia with nitrous oxide at normal pressure]. *C R Hebd Séances Acad Sci* 1883; 96: 1271–1274.
18. Smith AH. *The effects of high atmospheric pressure including the Caisson disease*. Brooklyn: Eagle Print, 1873.
19. Butler WP. Caisson disease during the construction of the Eads and Brooklyn Bridges: a review. *Undersea Hyperb Med* 2004; 31: 445–459.
20. Triger J. [Memoire on a compressed air appliance for drilling mine shafts and other work underwater and in submerged sands]. *C R Hebd Séances Acad Sci* 1841; 13: 884–896.
21. Triger J. [Letter to M. Arago]. *C R Hebd Séances Acad Sci* 1845; 20: 445–449.
22. Moir EW. Tunnelling by compressed air. *J Soc Arts* 1896; 44: 567–586.
23. Sellers LM. The fallibility of the Forrestian Principle "Semper primus pervenio maxima cum VI". *Laryngoscope* 1964; 74: 613–633.
24. Cunningham OJ. Therapeutic apparatus. US patent 1, 471,144. 1923.
25. Cunningham OJ. Oxygen therapy by means of compressed air. *Curr Res Anesth Analg* 1927; 6: 64–66.
26. American Medical Association Bureau of Investigation. The Cunningham "Tank treatment". *JAMA* 1928; 90: 1494–1496.
27. Kovac AL and Bause GS. Orval Cunningham: the man, his machine and his tank in Kansas City and Cleveland. In: Cooper MG, Ball CM and Thirlwell JR (eds) *History of Anaesthesia VIII. Proceedings of the 8th International Symposium on the History of Anaesthesia*. Sydney: Australian Society of Anaesthetists, 2016, pp. 401–406.
28. Current Comment. Useless tank to become useful tanks. *JAMA* 1942; 118: 1300.