**Autologous blood pleurodesis: A good choice in patients with persistent air leak**

Persistent air leak is a common complication after thorax surgery.[[1]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref1) While Rice and Kirby have reported a 15.2% rate of air leak persisting more than seven days after pulmonary lobectomy in 197 consecutive patients,[[2]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref2) air leak was observed in 27 (14.8%) of 182 patients treated by VATS wedge resection for spontaneous pneumothorax in another study.[[11]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref11)

Our patients consisted of secondary or primary spontaneous pneumothorax cases. No technique has proven superiority to others for the treatment of persistent air leaks. Some of the procedures applied by surgeons are; a drain*in situ*and a Heimlich valve,[[3]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref3) more aggressive approaches such as intra- pleural chemical agents (pleurodesis) or even primary repair by re-operation and injection of fibrin glue.[[4]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref4)

The aim of pleurodesis is to achieve pleural attachment.[[12]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref12) Therefore, expansion of the lungs and repair of pneumothorax before the procedure are mandatory. Pleurodesis is possible with agents such as tetracycline, talc powder and autologous blood.[[8]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref8) Tetracycline is an antibiotic commonly used for its sclerosing effect. According to Macoviak *et al*., tetracycline only produces an inflammatory reaction and scarring but no "patch" effect.[[12]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref12) Its efficiency is reported to be more or less 50%.[[7]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref7),[[8]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref8) Talc powder pleurodesis is probably effective through interleukin mediated polymorphonuclear neutrophil migration and monocyte infiltration with inflammation as a result. The risk of mesothelioma is minimized with the elimination of asbestos from talc powder.[[13]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref13)

On the other hand, restrictive respiratory distress has developed after talc powder treatment in 75 patients in the long-term in a study.[[7]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref7),[[13]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref13) In addition, sudden respiratory distress and death has been reported following talc powder use.[[13]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref13),[[14]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref14)

Pleurodesis with autologous blood was first performed by Robinson for treating patients with persistent air leaks due to spontaneous pneumothorax.[[15]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref15) Autologous blood pleurodesis could involve two factors working together: The blockage of a small air leak by forming a clot and the fibrogenic activity of the blood in the pleural cavity producing inflammation and irritation of both pleurae.[[12]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref12),[[15]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref15) Tetracycline and talc powder induce probably only inflammation and scarring, with no "patch" effect.

Autologous blood pleurodesis for the treatment of persistent air leaks, especially in patients with spontaneous pneumothorax, has been in use since 1992.[[9]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref9),[[16]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref16)In these studies the amount of autologous blood ranged between 50 to 250 ml as daily 50 ml injection repeated until success. We used only one single injection of 50 ml of blood in all our cases and obtained the desired effect also described by Dumire *et al*.[[8]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref8) and Cagirici *et al*.[[16]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref16) The reasons for not injecting more than 50 ml of blood included the concerns about injecting an ideal medium for bacteria in the pleural space in addition to the increased risk of bacterial contamination due to repeated manipulation of the drains.

In available literature, the time between the operation and the blood patch pleurodesis has varied from 10 to 23 days as seen in the series reported by Rivas de Andres,[[3]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref3) but has been up to five weeks.[[9]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref9)In all our cases we preferred to perform pleurodesis after the seventh day despite the existing discussions on the accurate time. Tetracycline induces only inflammation in the pleural cavity resulting in adhesion; air leak cessation is not expected before 3 to 5 days.[[12]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref12) We observed similar results in our study; air leak cessation time exceeded 48 hours in average with tetracycline use. A study reported air leak cessation in the first 12 hours in 72.7% of cases and cessation of all leaks in 48 hours using autologous blood[[17]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref17) while in two other series this period was under 24 hours.[[3]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref3),[[8]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref8) In our study, air leak cessation time was under 24 hours in the majority of the cases that underwent autologous blood pleurodesis and this seems to be the result of the "patch" effect. Success rates of 50-72% for tetracycline and 85-95% for talc pleurodesis have been reported in literature.[[6]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref6),[[7]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref7),[[14]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref14),[[18]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref18) However, success rates of 59-100% are reported with autologous blood pleurodesis adding that it is a simple, inexpensive and safe procedure. Success is even approved for cases with unexpanded lungs.[[8]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref8),[[9]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref9),[[15]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref15),[[16]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref16)

We achieved a success rate of 75.0% with autologous blood which was close to the success rate of talc powder (84.2%) but exceeding tetracycline (63.6%). De Vires and Wolfe[[19]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref19) reported persistent air leaks in 32% and Granke *et al*.[[20]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref20) in 22.4% of cases treated with a chest drain only. These high recurrences emphasize the necessity of pleurodesis in the treatment of persistent air leaks. Tanaka[[21]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref21) reported persistence in 18.8% patients treated with tetracycline while Jantzing[[22]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref22)reported persistence in 4% with quinacrine use. Our failure rates were 25.0%, 15.8% and 36.4% respectively for autologous blood, talc powder and tetracycline. The rate of recurrence at the ipsilateral side was reported higher (50%) with tetracycline use compared with the rates reported in literature. Reasons for failure in pleurodesis could be working with suboptimal techniques or inaccurate patients. Options in these cases are re performing sclerosing agents through the chest tube, thoracoscopic talc use or pleurectomy. We have chosen pleurectomy in our cases and no recurrence was observed.

Possible complications of talc and tetracycline are pleural thickening, diffuse fibrosis and decline in pulmonary functions. [[13]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref13),[[22]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref22) Restrictive respiratory insufficiency has been reported with talc use in the long term.[[6]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref6),[[13]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref13) We have observed serious decline in the PFT results of patients treated with tetracycline and talc powder compared with autologous blood that was statistically significant.

Pleurodesis with tetracycline can cause severe pain.[[8]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref8) Therefore, intrapleural lidocaine, in addition to intravenous sedation, is required in these patients while no anesthesia is necessary with autologous blood use. Pain was the most frequent side effect in our patients treated with tetracycline.

Side effects due to talc powder can be caused by the systemic reflection of severe inflammation in the pleural space. Dose related life-threatening side effects are also reported. Higher doses of talc seem to induce ARDS as reported by Antunes and Neville, which have used 10 g of talc.[[23]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref23) We have used five grams of talc in our patients and this could be the reason of no severe side effects except in one patient.

Chest pain and fever are the most frequent side effects of pleurodesing agents.[[17]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref17),[[20]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref20) Fever and chest pain which resolved in 24 hours with paracetamol use were observed in our patients

Life-threatening complications can occur after talc pleurodesis. [[7]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref7),[[14]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref14),[[18]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref18) We observed supraventricular tachycardia after talc pleurodesis in one patient that could not linked to an existing pathology but it resolved spontaneously.

Fever, pleural effusion and empyema are reported with autologous blood pleurodesis.[[15]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref15),[[16]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref16),[[17]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref17) Robinson found pleural infection in four per cent of patients treated with autologous blood in his study.[[15]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref15) We preferred to use a single injection of 50 ml of blood to prevent the accumulation of contaminated bacteria necessary for infecting the pleural space. Strict aseptic conditions were accomplished during the procedures. An infection occurred only in one patient in the form of empyema that resolved under antibiotherapy.

Obstruction of the catheter is an important problem which occurs during autologous blood pleurodesis. Thin catheters help obtain blood from the vena slowly and with a thin syringe and delay in introducing can end with obstruction resulting in tension pneumothorax.[[9]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref9) Therefore, the use of big sized chest tubes and syringes of 18 gauge and 0.9 mm for peripheral blood samples are recommended. Flushing the tube after the procedure with normal saline is also suggested. [[[8]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu#ref8),[[15]](http://www.thoracicmedicine.org/article.asp?issn=1817-1737;year=2009;volume=4;issue=4;spage=182;epage=186;aulast=Cobanoglu" \l "ref15)We accomplished all suggestions in literature and tension pneumothorax was not observed in any of our patients.

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| **Conclusion** |   |  |

We conclude that pleurodesis with autologous blood is an acceptable, painless, inexpensive and simple method in the treatment of recurrent primary spontaneous pneumothorax. We demonstrated that autologous blood is faster in ceasing air leaks when compared with talc powder and tetracycline. Its effectiveness is comparable to talc powder but superior to tetracycline with fewer side effects in comparison to both agents. The reason why this procedure is neglected could be the small number of cases and reports published. Further randomized clinical studies are needed to extend the use of autologous blood pleurodesis.

**Introduction**

Persistent air-leaks are frequently difficult clinical situations that are not infrequently associated with prolonged intercostal drainage and consequently lengths of hospitalization, especially in those with underlying chronic lung diseases with poor lung functions that preclude surgical or bronchoscopic interventions. Intrapleural instillations of tetracycline and talc slurry, commonly employed agents for chemical pleurodesis, have been employed in such clinical scenarios.

However, the supply of tetracycline derivatives has been erratic and their use is not uncommonly associated with side effects such as pain. (1) While the use of large-particle talc has recently been shown not to be associated with serious complications such as adult respiratory distress syndrome, (2) such preparations are currently quite expensive and results were mainly from malignant pleural effusions. Autologous blood, on the other hand, has been reported as a potentially effective, safe and cheap agent in preventing pneumothorax recurrence and treatment of air leaks since 1989. (3-4)

**Mechanisms of action**

Pleural inflammation, fibrotic change, neovascularization and finally collagen deposition were thought to be the necessary histopathological processes to result in successful pleurodesis. (5) Blood in the pleural cavity could be hypothesized to induce adhesions between the pleural layers with the induced inflammation, just like other agents. (6) However, it was observed that blood can only achieve minimal inflammatory changes in an animal study, when compared to the observed effects of talc and doxycline. (5) Hence, it is likely that the consequent cessation of air leaks observed is the result of a direct mechanical action of the fibrin due to a “blood patch” effect or sealing of the leak with blood clot or haematoma. (5,7) The other suggested mechanism included filling of the redundant pleural space by the clot produced. (8)

**Method of blood pleurodesis**

The method described by Dumire et al. (4) was most commonly utilized, though various modifications have been described. (9,10) Venous blood, usually 50-150ml, is obtained via conventional venipuncture and introduced immediately into the pleural drain via a rubber connecting tubing under aseptic technique. No heparin or disconnections of the drainage system is necessary. In order to prevent immediate efflux of the blood while allowing continued efflux of air from the persistent air leak to avoid pneumothorax, the drain tubing can be suspended from a drip stand (60cm above patient’s chest) to create an “inverted siphon” and only left to water-seal for 30min to 2 hours. During this period, the patient can be placed in different positions to facilitate the distribution of blood. The procedure can be repeated if air leak persists for in 2-3 days.

**Efficacy in treating persistent air leaks**

Most reports on the use of autologous blood at present have been case series and reports, with relatively few randomized controlled studies. A recent review of the efficacies in cases after lobectomy (9) demonstrated an early sealing effect (<24 hours) of at least 70% and all of the remainder achieved sealing with a second and rarely a third instillation in their review series. In the more recent reports (7,10,11) of its utilization in spontaneous pneumothoraces with persistent leakages, the overall efficacies ranged from 59% to 85%. It was interested to note that in the report with a lower efficacy (11), they have also applied autologous blood in patients whose lungs were not yet inflated with an overall success rate of 42% (4 out of 7 patients) in these cases. The timing of instillation ranged from 5 to 10 days of observed persistent leakage.

**Adverse effects**

In contrast to agents such as tetracycline derivatives, pain has not been described in case series and hence, sedation, analgesics and local anaesthetic agents was thought not necessary from the present literature. The major side effect reported was pleural infection with an incidence of 4% (3) and as such, active pleural sepsis with positive culture has been considered an absolute contraindication for it use. Although it was thought that it might be efficacious in even incomplete lung expansion as mentioned above, the collection of blood in the space might serve as a culture medium for microorganisms. (12) On the other hand, tension pneumothorax as a result of clot obstruction following blood pleurodesis via a 18 gauge catheter had also been described. (13) As a result, such a procedure might not be safe with small-bore catheters and sterile normal saline flush might be necessary and should be at hand during the procedure.

**Conclusion**

With the evidence and medical literature available so far, instillation of autologous blood appears to be potentially useful in the treatment of persistent air leaks in spontaneous pneumothoraces and after lobectomies. It appears attractive because of the low cost, fewer side effects and relative lack of systemic and potential long-term effects when compared to conventional sclerosing agents such as talc and tetracycline derivatives. Its use has been observed to be uncommon in a local survey ofHong Kong, with only 9 cases out of 258 with chemical pleurodesis performed in the year 2004(unpublished data). However, more randomized controlled studies and follow-up data would be useful to elucidate its usefulness in comparison to the other sclerosing agents or methods.

**OXYGEN DURING AIR TRAVEL**

**INTRODUCTION**

As air travel has become more common, travel opportunities have increased for people with serious medical conditions. This includes passengers with lung disease who require supplemental oxygen during air travel. Commercial air carriers' policies regarding in-flight oxygen vary considerably, potentially leading to a great deal of confusion for travelers.

This topic review provides an overview of the potential effects of air travel; measures to determine who may require in-flight oxygen; and steps to help patients plan ahead so that traveling with oxygen can be achieved safely, comfortably, and relatively easily.

**EFFECTS OF AIRLINE TRAVEL**

Traveling by airplane exposes people to decreased air pressure and lower than normal oxygen levels. For most people, these changes are not noticeable. However, for patients with certain underlying lung conditions, small atmospheric changes can have significant and potentially severe effects.

**Cabin pressure** — Air pressure drops as altitude increases. Thus, as an airplane ascends, the air pressure inside the plane is reduced. Inside commercial airplanes, pressurization of the cabin limits the fall of pressure. This allows the airplane to cruise at altitudes up to 40,000 feet without exposing travelers to dangerously low levels of air pressure.

Cabin pressurization levels vary by the type of airplane. The United States Federal Aviation Administration (FAA) requires that the cabin pressure on commercial airplanes be maintained at levels equivalent to the atmospheric pressure below 8,000 feet. The FAA allows for brief drops in air pressure for safety purposes only, such as to avoid bad weather conditions. The minimum air pressure to which travelers could be exposed for short periods of time is equal to that encountered 10,000 feet above sea level.

**Risks of exposure to low air pressure** — The effects of increased altitude and associated reductions in air pressure can result in expansion of the air or gas trapped within the body. Trapped air or gas can be located in many different places, including:

* Nasal sinuses
* Tubes within the ear
* Abnormal pockets within the lung (bullae)
* The space between the outer layer of the lung and the inner layer of the chest wall; air trapped in this region is referred to as a pneumothorax
* Internal organs in the abdominal cavity

As atmospheric pressure drops, trapped air expands. This explains the "ear-popping" with which most travelers are familiar. When air is trapped in the chest, gas expansion can be life-threatening.

Low air pressure during air travel also decreases the amount of oxygen in the air. This effect is modest and generally not noticeable for healthy travelers. For patients with significant lung disease, a small decrease in available oxygen can cause significant symptoms, especially with exercise. Although air travelers usually remain sitting and are relatively inactive during flight, even modest exertion (eg, walking to lavatory) under these conditions can cause low oxygen levels in up to 80 percent of people with lung disease.

Despite the theoretical risks associated with air travel, studies indicate that medical emergencies and deaths are uncommon in people with long-standing (chronic) lung disease who fly. Most studies suggest that medical emergencies occur in about one in every 19,000 to 40,000 travel episodes and that deaths occur in approximately one in every 3,200,000 travel episodes.

**WILL I REQUIRE IN-FLIGHT SUPPLEMENTAL OXYGEN?**

Patients with diseases that can cause low oxygen levels, particularly chronic obstructive pulmonary disease (COPD), may need oxygen supplementation in-flight. This is true even if the person does not use oxygen at home. (See ["Patient information: Chronic obstructive pulmonary disease (COPD), including emphysema (Beyond the Basics)"](http://www.uptodate.com/contents/chronic-obstructive-pulmonary-disease-copd-including-emphysema-beyond-the-basics?source=see_link).)

**Predictive tests** — The evaluation often includes measurement of the blood oxygen level using a finger oximeter and general tests of lung function. If you require supplemental oxygen on a daily basis, you may need an increased flow rate in-flight. If you do not require oxygen on a daily basis, but have borderline lung function, other tests may be recommended to calculate oxygen requirements during in-flight conditions. These include:

* Breathing a gas mixture with lower than normal levels of oxygen
* Testing in a special chamber where air pressure is lowered to simulate flight

Experts generally recommend supplemental oxygen for any patient whose in-flight oxygen level is predicted to fall below a certain point and for anyone who is known to have low oxygen levels on the ground.

**PREPARING FOR AIRLINE TRAVEL**

**Visit your doctor** — People who are at risk for low oxygen levels should discuss their condition with a clinician well in advance of the planned departure date. Here are some suggestions to make this process as efficient as possible:

* Determine if supplemental oxygen is needed several weeks to months before leaving. The studies necessary to determine the need for oxygen are best performed when your health is stable, within several weeks before the actual travel date. Most airlines require notification of the need for in-flight oxygen at least 48 hours before the trip, making it necessary to undergo such testing at least three days before travel.
* Learn what your oxygen requirements will be while flying, as well as during layovers and at the final destination (for those who require supplemental oxygen on the ground). Airlines do not provide oxygen for ground use. Speak with your doctor or other members of the healthcare team about arrangements to supply oxygen for each part of the trip. A local oxygen provider might be able to help with such arrangements.
* Obtain documentation of the need for oxygen from your doctor. Most airlines require a letter on the doctor's letterhead with his or her name and contact information, your specific underlying lung condition, approval for air travel, verification of need for in-flight oxygen, and information specifying the required oxygen flow rate in liters per minute, as well as duration of use ([figure 1](http://www.uptodate.com/contents/image?imageKey=PULM%2F71862&topicKey=PI%2F7961&source=see_link)). Be sure to bring enough copies of this letter for all flights.
* Make sure that you have an adequate supply of your usual medications for the trip.
* Some doctors will prescribe an emergency supply of certain medications, such as an antibiotic in case of a bacterial lung infection or an oral glucocorticoid (eg, prednisone) to prevent or reduce inflammation. Keep such medications in their original containers and be sure to pack them in carry-on luggage.
* Gather copies of prescriptions for your medications. You should carry multiple copies in case the luggage is delayed, lost, or stolen. Consider keeping copies in the carry-on luggage rather than in checked baggage.
* Obtain a list of recommended physicians at your destination(s) and along your travel route.

**Obtaining oxygen for air travel** — The Federal Aviation Administration does not allow travelers to carry their own oxygen tanks or liquid oxygen aboard commercial aircraft. Instead, most patients can use a Department of Transportation approved battery-powered portable oxygen concentrator. Airlines landing in the United States are now required to allow use of these devices throughout the flight.

You can get portable oxygen concentrators for short-term rental from an oxygen supply company. Examples of portable oxygen concentrators include AirSep Free Style, AirSep Life Style, Inogen One, Inogen One G2, Respironics EverGo, Sequal Eclipse, Delphi Medical Systems RS-00400, Invacare Corporation XPO2, DeVilbiss Healthcare iGo, International Biophysics Corporation Life Choice, and Oxlife Independence Oxygen Concentrator. You can use these on the ground and carry them onto the plane. These machines are battery-operated, so you need to bring enough 12-cell batteries for one and half times the anticipated duration of the flight. While you are in the airport waiting for boarding, you might be able to plug the portable oxygen concentrator into an electrical outlet to save your battery power.

Alternatively, some airlines provide oxygen that is supplied in an oxygen canister packaged in a flame proof "super box."

**"Shop around" for an appropriate airline** — Oxygen policies and charges can be very different, depending upon the airline. It is important to obtain the most up-to-date information about an airline’s specific requirements to make sure that your needs will be met. The Airline Oxygen Council of American web site ([www.airlineoxygencouncil.org](http://www.airlineoxygencouncil.org/)) lists various airlines' policies regarding in-flight oxygen use and equipment. The European Lung Foundation has compiled information on European airlines, whose rules and charges regarding in–flight oxygen may differ from those of American carriers ([www.european-lung-foundation.org](http://www.european-lung-foundation.org/)).

When contacting the airlines, begin by asking if they have a special services office, medical department, or a help desk to help travelers who need in-flight oxygen. The following is a list of suggested questions that may be helpful in clarifying a specific air carrier's oxygen policies:

* Does your airline accept passengers who require supplemental oxygen?
* Are portable oxygen concentrators acceptable or is oxygen supplied by the airline?
* How much notice do you require before the flight? Many airlines require 48- to 72-hour advance notice. However, some air carriers may require several days, one to two weeks, or as much as one month advance notice. This is particularly true of international flights.
* What documentation is required from my doctor? All carriers require some notification from the passenger's personal doctor concerning oxygen needs, usually a written prescription or an airline authorization form, although sometimes verbal notification is sufficient.
* Do you allow passengers to bring their empty oxygen equipment? Due to safety reasons, the Federal Aviation Administration (FAA) prohibits travelers from carrying their own partially- or completely-filled oxygen tank or liquid oxygen tank aboard commercial aircraft. However, some air carriers permit passengers to bring **empty** personal oxygen equipment on board or as checked baggage.
* Are there specific seat requirements? Some air carriers assign certain seats to oxygen-using passengers to accommodate their equipment.

**If the airline will be supplying the oxygen:**

* What do you charge for supplying in-flight oxygen and how is the charge determined? Specific price structures vary among carriers. Some carriers supply oxygen for free, while others charge varying rates, often ranging from about $100 to $250. However, fees may be as low as $50 or as high as $1,500. Charges may be based on a flat fee, the number of travel legs, the number of oxygen cylinders needed, or total air time. It is important to be aware that airlines may charge for each separate flight. Because health insurance may not cover such charges, it is important to consider the expense of in-flight oxygen when selecting among air carriers that serve the same destinations.
* Are passengers required to purchase an additional seat if they will need more than a certain number of oxygen cylinders?
* What liter flow options are available? The liter flow capability offered among different air carriers varies. For example, liter flow options may range from only one or two choices (eg, either 2 or 4 liters per minute) to an adjustable range of 1 to 15 liters per minute.
* Do you provide nasal cannulas or masks? A nasal cannula is a device that delivers oxygen via two small tubes inserted in the nostrils. Air carriers may offer nasal cannulas or masks only, or a choice between the two. In addition, they may allow you to bring and use your own cannula or mask.

**Verify the arrangements** — After deciding on an appropriate airline, be sure to make reservations as far in advance as you can. If there are any questions or concerns about the information you received while originally talking with the airline, call again to verify the information. In addition, make it a point to confirm your in-flight oxygen arrangements a few days before your flight, and be sure to arrive early.

**Take appropriate precautions when aboard** — Before your plane leaves the gate, you should also take certain additional precautions. You should make sure that:

* The oxygen equipment is working properly
* You have plenty of batteries for your portable oxygen concentrator; you need enough to last the whole flight comfortably
* For oxygen canisters in a “super box,” check that the cylinders are full
* The flow meter has been set to the proper liter flow per minute
* You have access to all of your medicines, including inhalers

If you have any questions or problems, notify a flight attendant immediately.

**BRACHYTHERAPY**

**Brachytherapy** (from the [Greek](http://en.wikipedia.org/wiki/Greek_language) word βραχυς *brachys*, meaning "short-distance"), also known as **internal radiotherapy**, **sealed source radiotherapy**, **curietherapy** or **endocurietherapy**, is a form of [radiotherapy](http://en.wikipedia.org/wiki/Radiotherapy) where a [radiation source](http://en.wikipedia.org/wiki/Radiation) is placed inside or next to the area requiring treatment. Brachytherapy is commonly used as an effective treatment for [cervical](http://en.wikipedia.org/wiki/Cervical_cancer), [prostate](http://en.wikipedia.org/wiki/Prostate_cancer), [breast](http://en.wikipedia.org/wiki/Breast_cancer), and [skin cancer](http://en.wikipedia.org/wiki/Skin_cancer) and can also be used to treat tumours in many other body sites.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1)

Brachytherapy can be used alone or in combination with other therapies such as surgery, [External Beam Radiotherapy](http://en.wikipedia.org/wiki/External_beam_radiotherapy) (EBRT) and[chemotherapy](http://en.wikipedia.org/wiki/Chemotherapy).

Brachytherapy contrasts with [unsealed source radiotherapy](http://en.wikipedia.org/wiki/Unsealed_source_radiotherapy) in which a therapeutic radioisotope is injected into the body to chemically localize to the tissue which requires destruction. It also contrasts to EBRT, in which high-energy x-rays (or occasionally gamma-rays from a radioisotope like [cobalt-60](http://en.wikipedia.org/wiki/Cobalt-60)) are directed at the tumour from outside the body. Brachytherapy instead involves the precise placement of short-range radiation-sources (radioisotopes) directly at the site of the cancerous tumour. These are enclosed in a protective capsule or wire which allows the ionizing radiation to escape to treat and kill surrounding tissue, but prevents the charge of radioisotope from moving or dissolving in body fluids. The capsule may be removed later, or (with some radioisotopes) it may be allowed to remain in place.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 1[[2]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Stewart_2007-2) A key feature of brachytherapy is that the irradiation only affects a very localized area around the radiation sources. Exposure to radiation of healthy tissues further away from the sources is therefore reduced. In addition, if the patient moves or if there is any movement of the tumour within the body during treatment, the radiation sources retain their correct position in relation to the tumour. These characteristics of brachytherapy provide advantages over EBRT - the tumour can be treated with very high doses of localised radiation, whilst reducing the probability of unnecessary damage to surrounding healthy tissues.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 1[[2]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Stewart_2007-2)

A course of brachytherapy can be completed in less time than other radiotherapy techniques. This can help reduce the chance of surviving cancer cells dividing and growing in the intervals between each radiotherapy dose.[[2]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Stewart_2007-2) Patients typically have to make fewer visits to the radiotherapy clinic compared with EBRT, and the treatment is often performed on an outpatient basis. This makes treatment accessible and convenient for many patients.[[3]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-BMJGroup-2009-3)[[4]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Kelley_2007-4) These features of brachytherapy reflect that most patients are able to tolerate the brachytherapy procedure very well.

Brachytherapy represents an effective treatment option for many types of cancer. Treatment results have demonstrated that the cancer cure rates of brachytherapy are either comparable to surgery and EBRT, or are improved when used in combination with these techniques.[[5]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Viswanathan_2007-5)[[6]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Pickles-2009-6)[[7]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Haie-Meder-2009-7)[[8]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Batterman-2004-8)[[9]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Galalae-2004-9)[[10]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Hoskin-2007-10)[[11]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Pieters_-2009-11)[[12]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Nelson-2009-12) In addition, brachytherapy is associated with a low risk of serious adverse side effects.[[13]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Ferrer-2008-13)[[14]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Frank-2007-14)

## Types

Different types of brachytherapy can be defined according to (1) the [placement of the radiation sources](http://en.wikipedia.org/wiki/Brachytherapy#Source_placement) in the target treatment area, (2) the [rate or ‘intensity’ of the irradiation dose](http://en.wikipedia.org/wiki/Brachytherapy#Dose_rate)delivered to the tumour, and (3) the [duration of dose delivery](http://en.wikipedia.org/wiki/Brachytherapy#Duration_of_dose_delivery).

**Source placement**

The two main types of brachytherapy treatment in terms of the placement of the radioactive source are **interstitial** and **contact**.

* In the case of interstitial brachytherapy, the sources are placed directly in the target tissue of the affected site, such as the prostate or breast.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 1
* Contact brachytherapy involves placement of the radiation source in a space next to the target tissue.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 1 This space may be a body cavity (**intracavitary** brachytherapy) such as the [cervix](http://en.wikipedia.org/wiki/Cervix), [uterus](http://en.wikipedia.org/wiki/Uterus) or [vagina](http://en.wikipedia.org/wiki/Vagina); a body lumen (**intraluminal** brachytherapy) such as the [trachea](http://en.wikipedia.org/wiki/Vertebrate_trachea) or [oesophagus](http://en.wikipedia.org/wiki/Oesophagus%22%20%5Co%20%22Oesophagus); or externally (**surface** brachytherapy) such as the[skin](http://en.wikipedia.org/wiki/Skin).[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 1 A radiation source can also be placed in blood vessels (**intravascular** brachytherapy) for the treatment of [coronary in-stent restenosis](http://en.wikipedia.org/wiki/Coronary_stent#Restenosis).[[21]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Giap_2007-21)

### Dose rate

The dose rate of brachytherapy refers to the level or ‘intensity’ with which the radiation is delivered to the surrounding medium and is expressed in [Grays](http://en.wikipedia.org/wiki/Gray_%28unit%29) per hour (Gy/h).

* **Low-dose rate(LDR)** brachytherapy involves implanting radiation sources that emit radiation at a rate of up to 2 Gy·h−1.[[22]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Thomadsen_2005-22) LDR brachytherapy is commonly used for cancers of the oral cavity,[[23]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Mazaron-2009-23) [oropharynx](http://en.wikipedia.org/wiki/Oropharynx%22%20%5Co%20%22Oropharynx),[[23]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Mazaron-2009-23) [sarcomas](http://en.wikipedia.org/wiki/Sarcomas)[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 27 and [prostate cancer](http://en.wikipedia.org/wiki/Prostate_cancer)[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 20[[24]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Koukourakis-2009-24)
* **Medium-dose rate (MDR)** brachytherapy is characterized by a medium rate of dose delivery, ranging between 2 Gy·h−1 to 12 Gy·h−1.[[22]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Thomadsen_2005-22)
* **High-dose rate (HDR)** brachytherapy is when the rate of dose delivery exceeds 12 Gy·h−1.[[22]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Thomadsen_2005-22) The most common applications of HDR brachytherapy are in tumours of the[cervix](http://en.wikipedia.org/wiki/Cervix), [esophagus](http://en.wikipedia.org/wiki/Esophagus), [lungs](http://en.wikipedia.org/wiki/Lungs), [breasts](http://en.wikipedia.org/wiki/Breasts) and [prostate](http://en.wikipedia.org/wiki/Prostate).[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1) Most HDR treatments are performed on an outpatient basis, but this is dependent on the treatment site.[[25]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Nag-2004-25)
* **Pulsed-dose rate (PDR)** brachytherapy involves short pulses of radiation, typically once an hour, to simulate the overall rate and effectiveness of LDR treatment. Typical tumour sites treated by PDR brachytherapy are gynaecological[[1]](http://en.wikipedia.org/wiki/Brachytherapy%22%20%5Cl%20%22cite_note-GEC-ESTRO-1):Ch. 14 and head and neck cancers.[[23]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Mazaron-2009-23)

### Duration of dose delivery

The placement of radiation sources in the target area can be temporary or permanent.

* Temporary brachytherapy involves placement of radiation sources for a set duration (usually a number of minutes or hours) before being withdrawn.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 1 The specific treatment duration will depend on many different factors, including the required rate of dose delivery and the type, size and location of the cancer. In LDR and PDR brachytherapy, the source typically stays in place up to 24 hours before being removed, while in HDR brachytherapy this time is typically a few minutes.[[26]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Flynn_2005-26)
* Permanent brachytherapy, also known as seed implantation, involves placing small LDR radioactive seeds or pellets (about the size of a grain of rice) in the tumour or treatment site and leaving them there permanently to gradually decay. Over a period of weeks or months, the level of radiation emitted by the sources will decline to almost zero. The inactive seeds then remain in the treatment site with no lasting effect.[[27]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Moule-2009-27) Permanent brachytherapy is most commonly used in the treatment of [prostate cancer](http://en.wikipedia.org/wiki/Prostate_cancer).[[24]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Koukourakis-2009-24)

## Clinical applications

**Body sites in which brachytherapy can be used to treat cancer**

Brachytherapy is commonly used to treat cancers of the [cervix](http://en.wikipedia.org/wiki/Cervix), [prostate](http://en.wikipedia.org/wiki/Prostate), [breast](http://en.wikipedia.org/wiki/Breast), and[skin](http://en.wikipedia.org/wiki/Skin).[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1)

Brachytherapy can also be used in the treatment of tumours of the [brain](http://en.wikipedia.org/wiki/Human_brain), [eye](http://en.wikipedia.org/wiki/Human_eye), head and neck region (lip, [floor of mouth](http://en.wikipedia.org/wiki/Floor_of_mouth), tongue, [nasopharynx](http://en.wikipedia.org/wiki/Nasopharynx%22%20%5Co%20%22Nasopharynx) and [oropharynx](http://en.wikipedia.org/wiki/Oropharynx%22%20%5Co%20%22Oropharynx)),[[23]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Mazaron-2009-23) respiratory tract ([trachea](http://en.wikipedia.org/wiki/Vertebrate_trachea) and [bronchi](http://en.wikipedia.org/wiki/Bronchi)), digestive tract ([oesophagus](http://en.wikipedia.org/wiki/Oesophagus%22%20%5Co%20%22Oesophagus), [gall bladder](http://en.wikipedia.org/wiki/Gall_bladder), [bile-ducts](http://en.wikipedia.org/wiki/Bile_duct), [rectum](http://en.wikipedia.org/wiki/Rectum%22%20%5Co%20%22Rectum),[anus](http://en.wikipedia.org/wiki/Anus)),[[28]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Dvor.C3.A1k-2002-28) urinary tract ([bladder](http://en.wikipedia.org/wiki/Bladder), [urethra](http://en.wikipedia.org/wiki/Urethra), [penis](http://en.wikipedia.org/wiki/Penis)), female reproductive tract ([uterus](http://en.wikipedia.org/wiki/Uterus), [vagina](http://en.wikipedia.org/wiki/Vagina%22%20%5Co%20%22Vagina),[vulva](http://en.wikipedia.org/wiki/Vulva)), and soft tissues.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1)

As the radiation sources can be precisely positioned at the tumour treatment site, brachytherapy enables a high dose of radiation to be applied to a small area. Furthermore, because the radiation sources are placed in or next to the target tumour, the sources maintain their position in relation to the tumour when the patient moves or if there is any movement of the tumour within the body. Therefore, the radiation sources remain accurately targeted. This enables clinicians to achieve a high level of dose conformity – i.e. ensuring the whole of the tumour receives an optimal level of radiation. It also reduces the risk of damage to healthy tissue, organs or structures around the tumour,[[25]](http://en.wikipedia.org/wiki/Brachytherapy%22%20%5Cl%20%22cite_note-Nag-2004-25) thus enhancing the chance of cure and preservation of organ function.

The use of HDR brachytherapy enables overall treatment times to be reduced compared with EBRT.[[29]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Joseph-2008-29)[[30]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Holmboe-2000-30) Patients receiving brachytherapy generally have to make fewer visits for radiotherapy compared with EBRT, and overall radiotherapy treatment plans can be completed in less time.[[31]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Hoskin_2005_book-31) Many brachytherapy procedures are performed on an outpatient basis. This convenience may be particularly relevant for patients who have to work, older patients, or patients who live some distance from treatment centres, to ensure that they have access to radiotherapy treatment and adhere to treatment plans. Shorter treatment times and outpatient procedures can also help improve the efficiency of radiotherapy clinics.[[32]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Guedea-2008-32)[[33]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Quang-2007-33)

Brachytherapy can be used with the aim of curing the cancer in cases of small or locally advanced tumours, provided the cancer has not metastasized (spread to other parts of the body). In appropriately selected cases, brachytherapy for primary tumours often represents a comparable approach to surgery, achieving the same probability of cure and with similar side effects.[[34]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Guedea-2009-34)[[35]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Litwin-2007-35) However, in locally advanced tumours, surgery may not routinely provide the best chance of cure and is often not technically feasible to perform. In these cases radiotherapy, including brachytherapy, offers the only chance of cure.[[36]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Pistis_-2009-36)[[37]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Lertsanguansinchai-2004-37) In more advanced disease stages, brachytherapy can be used as palliative treatment for symptom relief from pain and bleeding.

In cases where the tumour is not easily accessible or is too large to ensure an optimal distribution of irradiation to the treatment area, brachytherapy can be combined with other treatments, such as EBRT and/or surgery.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 1 Combination therapy of brachytherapy exclusively with chemotherapy is rare.[[38]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Roddiger-2006-38)

### Cervical cancer

Brachytherapy is commonly used in the treatment of early or locally confined [cervical cancer](http://en.wikipedia.org/wiki/Cervical_cancer) and is a standard of care in many countries.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 14[[39]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Gaffney-2007-39)[[40]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-NICE-IPG160-40)[[41]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Viswanathan-ABS-41)[[42]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Viswanathan-2009-42) Cervical cancer can be treated with either LDR, PDR or HDR brachytherapy.[[7]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Haie-Meder-2009-7)[[41]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Viswanathan-ABS-41)[[43]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Kim-2009-43) Used in combination with EBRT, brachytherapy can provide better outcomes than EBRT alone.[[5]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Viswanathan_2007-5) The precision of brachytherapy enables a high dose of targeted radiation to be delivered to the cervix, while minimising radiation exposure to adjacent tissues and organs.[[40]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-NICE-IPG160-40)[[41]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Viswanathan-ABS-41)[[44]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-P.C3.B6tter-2008-44)[[45]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-P.C3.B6tter-2006-45)

The chances of staying free of disease (disease-free survival) and of staying alive (overall survival) are similar for LDR, PDR and HDR treatments.[[37]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Lertsanguansinchai-2004-37)[[46]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Hareyama-2002-46) However, a key advantage of HDR treatment is that each dose can be delivered on an outpatient basis with a short administration time[[5]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Viswanathan_2007-5) providing greater convenience for many patients.

### Prostate cancer

Brachytherapy to treat [prostate cancer](http://en.wikipedia.org/wiki/Prostate_cancer) can be given either as permanent LDR seed implantation or as temporary HDR brachytherapy.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 20[[47]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Merrick-ABS-47)[[48]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Hsu-ABS-48)

Permanent seed implantation is suitable for patients with a localised tumour and good prognosis [[8]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Batterman-2004-8)[[47]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Merrick-ABS-47)[[49]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Ash_2005-49)[[50]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Morris-2009-50) and has been shown to be a highly effective treatment to prevent the cancer from returning.[[6]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Pickles-2009-6)[[8]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Batterman-2004-8) The survival rate is similar to that found with EBRT or surgery ([radical prostatectomy](http://en.wikipedia.org/wiki/Radical_prostatectomy)), but with fewer side effects such as [impotence](http://en.wikipedia.org/wiki/Impotence) and [incontinence](http://en.wikipedia.org/wiki/Urinary_incontinence).[[14]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Frank-2007-14)The procedure can be completed quickly and patients are usually able to go home on the same day of treatment and return to normal activities after 1 to 2 days.[[3]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-BMJGroup-2009-3) Permanent seed implantation is often a less invasive treatment option compared to the surgical removal of the prostate.[[3]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-BMJGroup-2009-3)

Temporary HDR brachytherapy is a newer approach to treating prostate cancer, but is currently less common than seed implantation. It is predominately used as to provide an extra dose in addition to EBRT (known as ‘”boost” therapy) as it offers an alternative method to deliver a high dose of radiation therapy that conforms to the shape of the tumour within the prostate, while sparing radiation exposure to surrounding tissues.[[9]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Galalae-2004-9)[[10]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Hoskin-2007-10)[[11]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Pieters_-2009-11)[[48]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Hsu-ABS-48)[[49]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Ash_2005-49)[[51]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Pisansky-2008-51) HDR brachytherapy as a boost for prostate cancer also means that the EBRT course can be shorter than when EBRT is used alone.[[9]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Galalae-2004-9)[[10]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Hoskin-2007-10)[[36]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Pistis_-2009-36)[[51]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Pisansky-2008-51)

### Breast cancer

Radiation therapy is standard of care for women who have undergone [lumpectomy](http://en.wikipedia.org/wiki/Lumpectomy) or [mastectomy](http://en.wikipedia.org/wiki/Mastectomy) surgery, and is an integral component of breast-conserving therapy.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 18[[52]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Keisch-ABS-52)Brachytherapy can be used after surgery, before chemotherapy or palliatively in the case of advanced disease.[[53]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Hoskin_2005-53) Brachytherapy to treat [breast cancer](http://en.wikipedia.org/wiki/Breast_cancer) is usually performed with HDR temporary brachytherapy. Post surgery, breast brachytherapy can be used as a “boost” following irradiation of the whole breast using EBRT.[[52]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Keisch-ABS-52)[[54]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Polg.C3.A1r-2009-54) More recently, brachytherapy alone is applied in a technique called APBI (accelerated partial breast irradiation), involving delivery of radiation to only the immediate region surrounding the original tumour.[[12]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Nelson-2009-12)[[52]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Keisch-ABS-52)[[54]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Polg.C3.A1r-2009-54)

The main benefit of breast brachytherapy compared to EBRT is that a high dose of radiation can be precisely applied to the tumour while sparing radiation to healthy breast tissues and underlying structures such as the ribs and lungs.[[53]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Hoskin_2005-53) APBI can typically be completed over the course of a week.[[12]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Nelson-2009-12) The option of brachytherapy may be particularly important in ensuring that working women, the elderly or women without easy access to a treatment centre, are able to benefit from breast-conserving therapy due to the short treatment course compared with EBRT (which often requires more visits over the course of 1–2 months).[[4]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Kelley_2007-4) Brachytherapy has demonstrated excellent local control of breast cancer at follow-up of up to 6 years post treatment.[[12]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Nelson-2009-12)[[55]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-King-2000-55)[[56]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Go.C2.B4mez-Iturriaga-2008-56) A study is underway to compare patient outcomes of APBI in comparison to EBRT at up to 10 years after treatment.[[57]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Breast-cancer-trial-57)

There are two methods that can be used to deliver breast brachytherapy:

* **Interstitial breast brachytherapy** using multiple catheters
* **Intracavitary breast brachytherapy** using a balloon catheter

Interstitial breast brachytherapy involves the temporary placement of several flexible plastic catheters in the breast tissue. These are carefully positioned to allow optimal targeting of radiation to the treatment area while sparing the surrounding breast tissue.[[4]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Kelley_2007-4) The catheters are connected to an [afterloader](http://en.wikipedia.org/wiki/Brachytherapy%22%20%5Cl%20%22Procedure), which delivers the planned radiation dose to the treatment area. Interstitial breast brachytherapy can be used as “boost” after EBRT, or as APBI.[[54]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Polg.C3.A1r-2009-54)

Intracavitary breast brachytherapy (also known as “balloon brachytherapy”) involves the placement of a single catheter into the breast cavity left after the removal of the tumour (lumpectomy).[[4]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Kelley_2007-4) The catheter can be placed at the time of the lumpectomy or postoperatively.[[4]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Kelley_2007-4) Via the catheter, a balloon is then inflated in the cavity. The catheter is then connected to an [afterloader](http://en.wikipedia.org/wiki/Brachytherapy%22%20%5Cl%20%22Procedure), which delivers the radiation dose through the catheter and into the balloon. Currently, intracavitary breast brachytherapy is only routinely used for APBI.[[58]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Shah-2010-58)

There are also devices that combine the features of interstitial and intracavitary breast brachytherapy (e.g. SAVI). These devices use multiple catheters but are inserted through a single-entry point in the breast. Studies suggest the use of multiple catheters enables physicians to target the radiation more precisely.[[59]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-59)[[60]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-60)

### Skin cancer

HDR brachytherapy for nonmelanomatous [skin cancer](http://en.wikipedia.org/wiki/Skin_cancer), such as [basal cell carcinoma](http://en.wikipedia.org/wiki/Basal_cell_carcinoma) and [squamous cell carcinoma](http://en.wikipedia.org/wiki/Squamous_cell_carcinoma%22%20%5Co%20%22Squamous%20cell%20carcinoma), provides an alternative treatment option to surgery. This is especially relevant for cancers on the nose, ears, eyelids or lips, where surgery may cause disfigurement or require extensive reconstruction.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 28 Various applicators can be used to ensure close contact between the radiation source(s) and the skin, which conform to the curvature of the skin and help ensure precision delivery of the optimal irradiation dose.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 28

Brachytherapy for skin cancer provides good cosmetic results and clinical efficacy; studies with up to 5 years follow-up have shown that brachytherapy is highly effective in terms local control, and is comparable to EBRT.[[61]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Guix-2000-61)[[62]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Sedda-2008-62)[[63]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Rio-2005-63) Treatment times are typically short, providing convenience for patients.[[64]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Musmacher-2006-64) It has been suggested that brachytherapy may become a standard of treatment for skin cancer in the near future.[[64]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Musmacher-2006-64)

### Coronary/Vascular

Brachytherapy can be used in the treatment of [coronary in-stent restenosis](http://en.wikipedia.org/wiki/Coronary_stent#Restenosis), in which a catheter is placed inside blood vessels, through which sources are inserted and removed.[[65]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-ESC-2005-65)In treating In-stent restenosis (ISR) Drug Eluting stents (DES)have been found to be superior to Intracoronary Brachytherapy (ICBT). However, there is continued interest in vascular brachytherapy for persistent restenosis in failed stents and vein grafts. The therapy has also been investigated for use in the treatment of [peripheral vasculature stenosis](http://en.wikipedia.org/wiki/Peripheral_vascular_disease)[[66]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Sidawy-2002-66) and considered for the treatment of [atrial fibrillation](http://en.wikipedia.org/wiki/Atrial_fibrillation%22%20%5Co%20%22Atrial%20fibrillation).[[67]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-P.C3.A9rez-Castellano-2006-67)

**Side effects**

The likelihood and nature of potential acute, sub-acute or long-term side-effects associated with brachytherapy depends on the location of the tumour being treated and the type of brachytherapy being used.

### Acute

Acute side effects associated with brachytherapy include localised bruising, swelling, bleeding, discharge or discomfort within the implanted region. These usually resolve within a few days following completion of treatment.[[68]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Macmillan-brachytherapy-68) Patients may also feel fatigued for a short period following treatment.[[68]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Macmillan-brachytherapy-68)[[69]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Fieler-1997-69)

Brachytherapy treatment for cervical or prostate cancer can cause acute and transient urinary symptoms such as urinary retention, urinary incontinence or painful urination (dysuria).[[14]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Frank-2007-14)[[70]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Doust-2004-70)[[71]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Magn.C3.A9-2009-71) Transient increased bowel frequency, diarrhoea, constipation or minor rectal bleeding, may also occur.[[14]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Frank-2007-14)[[70]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Doust-2004-70)[[71]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Magn.C3.A9-2009-71) Acute and subacute side effects usually resolve over a matter of days or a few weeks. In the case of permanent (seed) brachytherapy for prostate cancer, there is a small chance that some seeds may migrate out of the treatment region into the bladder or urethra and be passed in the urine.

Brachytherapy for skin cancer may result in a shedding of the outer layers of skin (desquamation) around the area of treatment in the weeks following therapy, which typically heals in 5–8 weeks.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 28 If the cancer is located on the lip, ulceration may occur as a result of brachytherapy, but usually resolves after 4–6 weeks.[[72]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Casino-2006-72)

Most of the acute side effects associated with brachytherapy can be treated with medication or through dietary changes, and usually disappear over time (typically a matter of weeks), once the treatment is completed. The acute side effects of HDR brachytherapy are broadly similar to EBRT.[[69]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Fieler-1997-69)

### Long-term

In a small number of people, brachytherapy may cause long-term side effects due to damage or disruption of adjacent tissues or organs. Long-term side effects are usually mild or moderate in nature. For example, urinary and digestive problems may persist as a result of brachytherapy for cervical or prostate cancer, and may require ongoing management.[[14]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Frank-2007-14)[[70]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Doust-2004-70)[[71]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Magn.C3.A9-2009-71)

Brachytherapy for prostate cancer may cause erectile dysfunction in approximately 15-30% of patients.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 20[[27]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Moule-2009-27) However, the risk of erectile dysfunction is related to age (older men are at a greater risk than younger men) and also the level of erectile function prior to receiving brachytherapy. In patients who do experience erectile dysfunction, the majority of cases can successfully be treated with drugs such as [Viagra](http://en.wikipedia.org/wiki/Viagra).[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 20 Importantly, the risk of erectile dysfunction after brachytherapy is less than after [radical prostatectomy](http://en.wikipedia.org/wiki/Radical_prostatectomy).[[34]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Guedea-2009-34)[[70]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Doust-2004-70)

Brachytherapy for breast or skin cancer may cause scar tissue to form around the treatment area. In the case of breast brachytherapy, fat necrosis may occur as a result of fatty acids entering the breast tissues. This can cause the breast tissue to become swollen and tender. Fat necrosis is a benign condition and typically occurs 4–12 months after treatment and affects about 2% of patients.[[73]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Vicini-2009-73)[[74]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Humonc-breast-74)

## [[edit](http://en.wikipedia.org/w/index.php?title=Brachytherapy&action=edit&section=15)]Safety around others

Patients often ask if they need to have special safety precautions around family and friends after receiving brachytherapy. If temporary brachytherapy is used, no radioactive sources remain in the body after treatment. Therefore, there is no radiation risk to friends or family from being in close proximity with them.[[75]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-rtanswers.com-75)

If permanent brachytherapy is used, low dose radioactive sources (seeds) are left in the body after treatment - the radiation levels are very low and decrease over time. In addition, the irradiation only affects tissues within a few millimeters of the radioactive sources (i.e. the tumour being treated). As a precaution, some people receiving permanent brachytherapy may be advised to not hold any small children or be too close to pregnant women for a short time after treatment. Radiation oncologists or nurses can provide specific instructions to patients and advise for how long they need to be careful.[[75]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-rtanswers.com-75)

## Procedure

### Initial planning

In order to accurately plan the brachytherapy procedure, a thorough clinical examination is performed to understand the characteristics of the tumour. In addition, a range of imaging modalities can be used to visualise the shape and size of the tumour and its relation to surrounding tissues and organs. These include x-ray radiography, ultrasound, computed axial tomography (CT or CAT) scans and magnetic resonance imaging (MRI).[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 5 The data from many of these sources can be used to create a 3D visualisation of the tumour and the surrounding tissues.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 5

Using this information, a plan of the optimal distribution of the radiation sources can be developed. This includes consideration of how the source carriers (applicators), which are used to deliver the radiation to the treatment site, should be placed and positioned.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 5 Applicators are non-radioactive and are typically needles or plastic catheters. The specific type of applicator used will depend on the type of cancer being treated and the characteristics of the target tumour.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 5

This initial planning helps to ensure that ‘cold spots’ (too little irradiation) and ‘hot spots’ (too much irradiation) are avoided during treatment, as these can respectively result in treatment failure and side-effects.[[44]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-P.C3.B6tter-2008-44)

### [[edit](http://en.wikipedia.org/w/index.php?title=Brachytherapy&action=edit&section=18)]Insertion and imaging of the applicator(s)

Before radioactive sources can be delivered to the tumour site, the applicators have to be inserted and correctly positioned in line with the initial planning.

Imaging techniques, such as x-ray, fluoroscopy and ultrasound are typically used to help guide the placement of the applicators to their correct positions and to further refine the treatment plan.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 5 CAT scans and MRI can also be used.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 5 Once the applicators are inserted, they are held in place against the skin using sutures or adhesive tape to prevent them from moving. Once the applicators are confirmed as being in the correct position, further imaging can be performed to guide detailed treatment planning.

### Creation of a virtual patient

The images of the patient with the applicators in situ are imported into treatment planning software and the patient is brought into a dedicated shielded room for treatment. The treatment planning software enables multiple 2D images of the treatment site to be translated into a 3D ‘virtual patient’, within which the position of the applicators can be defined.[[1]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GEC-ESTRO-1):Ch. 5 The spatial relationships between the applicators, the treatment site and the surrounding healthy tissues within this ‘virtual patient’ are a copy of the relationships in the actual patient.

### Optimizing the irradiation plan

**Refinement of the treatment plan during the brachytherapy procedure.**

To identify the optimal spatial and temporal distribution of radiation sources within the applicators of the implanted tissue or cavity, the treatment planning software allows virtual radiation sources to be placed within the virtual patient. The software shows a graphical representation of the distribution of the irradiation. This serves as a guide for the brachytherapy team to refine the distribution of the sources and provide a treatment plan that is optimally tailored to the anatomy of each patient before actual delivery of the irradiation begins.[[76]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-GYNOpt-2009-76) This approach is sometimes called ‘dose-painting’.

### Treatment delivery

The radiation sources used for brachytherapy are always enclosed within a non-radioactive capsule. The sources can be delivered manually, but are more commonly delivered through a technique known as ‘afterloading’.

Manual delivery of brachytherapy is limited to a few LDR applications, due to risk of radiation exposure to clinical staff.[[26]](http://en.wikipedia.org/wiki/Brachytherapy#cite_note-Flynn_2005-26)

In contrast, afterloading involves the accurate positioning of non-radioactive applicators in the treatment site, which are subsequently loaded with the radiation sources. In manual afterloading, the source is delivered into the applicator by the operator.

Remote afterloading systems provide protection from radiation exposure to healthcare professionals by securing the radiation source in a shielded safe. Once the applicators are correctly positioned in the patient, they are connected to an ‘afterloader’ machine (containing the radioactive sources) through a series of connecting guide tubes. The treatment plan is sent to the afterloader, which then controls the delivery of the sources along the guide tubes into the pre-specified positions within the applicator. This process is only engaged once staff are removed from the treatment room. The sources remain in place for a pre-specified length of time, again following the treatment plan, following which they are returned along the tubes to the afterloader.

On completion of delivery of the radioactive sources, the applicators are carefully removed from the body. Patients typically recover quickly from the brachytherapy procedure, enabling it to often be performed on an outpatient basis.

## Electronic brachytherapy

Electronic brachytherapy involves placement of miniature low energy x-ray tube sources into a pre-positioned applicator within body/tumour cavities to rapidly deliver high doses to target tissues while maintaining low doses to distant non-target tissues.

**Environmental hazard**

Due to the small size of brachytherapy sources and low control in early decades, there is a risk that some of these have escaped into the environment to become [orphaned sources](http://en.wikipedia.org/wiki/Orphaned_source). A radium needle was found in a Prague playground in 2011, radiating 500 µSv/h from one metre away.

**INTRODUCTION**

Airway stents, also known as tracheobronchial prostheses, are tube-shaped devices that are inserted into an airway. They are usually placed bronchoscopically and can be used to treat a variety of large airway diseases. The indications for airway stenting, types of stents, insertion technique, and potential complications are reviewed here. Other strategies for managing central airway obstruction are discussed separately. (See ["Diagnosis and management of central airway obstruction"](http://www.uptodate.com/contents/diagnosis-and-management-of-central-airway-obstruction?source=see_link).)

**PATIENT SELECTION**

**Indications** — There are many indications for airway stenting [[1-13](http://www.uptodate.com/contents/airway-stents/abstract/1-13)], including the following:

* Malignant tracheobronchial obstruction in a patient who is undergoing external beam radiation and/or chemotherapy, or who has exhausted his or her curative therapeutic options.
* Malignant tracheobronchial obstruction that persists despite endobronchial resection and dilation.
* Postintubation subglottic stenosis that fails endobronchial resection and dilation.
* Benign tracheal or bronchial stenosis in a patient who is not a surgical candidate, who is awaiting a response to systemic therapy, or for whom surgical resection is pending.
* Localized severe expiratory central airway collapse, such as tracheobronchomalacia or selected cases of excessive dynamic airway collapse of any etiology [[14](http://www.uptodate.com/contents/airway-stents/abstract/14)].
* Anastomotic stricture or dehiscence following lung or heart-lung transplantation.
* Tracheal- or bronchial-esophageal fistula ([image 1](http://www.uptodate.com/contents/airway-stents#subscribeMessage)).

**Contraindications** — Airways stents are generally inserted bronchoscopically using either general anesthesia or procedural sedation. Thus, contraindications to bronchoscopy, general anesthesia, and/or procedural sedation are also considered contraindications to airway stenting. These are reviewed separately. (See ["Flexible bronchoscopy: Indications and contraindications"](http://www.uptodate.com/contents/flexible-bronchoscopy-indications-and-contraindications?source=see_link) and ["Overview of anesthesia and anesthetic choices"](http://www.uptodate.com/contents/overview-of-anesthesia-and-anesthetic-choices?source=see_link) and ["Procedural sedation in adults", section on 'Contraindications and precautions'](http://www.uptodate.com/contents/procedural-sedation-in-adults?source=see_link&anchor=H4#H4).)

Airway stenting is also contraindicated prior to laser therapy, endobronchial electrocautery, or argon plasma coagulation because such therapies can burn or break airway stents [[15](http://www.uptodate.com/contents/airway-stents/abstract/15)]. (See ["Bronchoscopic laser resection"](http://www.uptodate.com/contents/bronchoscopic-laser-resection?source=see_link) and ["Endobronchial electrocautery"](http://www.uptodate.com/contents/endobronchial-electrocautery?source=see_link) and ["Argon plasma coagulation in the management of airway disease"](http://www.uptodate.com/contents/argon-plasma-coagulation-in-the-management-of-airway-disease?source=see_link).) In contrast, external beam radiation therapy and brachytherapy are NOT contraindications to airway stenting.

## Operative Steps

### Anesthesia

Patients undergoing flexible bronchoscopy for evaluation of their airway problems are routinely managed with local anesthesia and sedation. In such patients, however, general anesthesia and rigid bronchoscopy should be immediately available if required, especially when a critical obstruction of the central airway is present.

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Rigid bronchoscopy requires general anesthesia but muscle paralysis is generally not indicated. In most patients ventilation can be managed through the accessory port of the rigid bronchoscope; occasionally a jet ventilation catheter may be inserted, but it usually adds complexity without evident benefit. Generous topical anesthetic should be administered, starting with its instillation in the upper airway through a laryngeal syringe (**Figure 4**) before inserting the rigid bronchoscope. Additional topical anesthetic is administered during the procedure, in particular before using laser, prior to dilation, and before placing stents, to inhibit the cough reflex. General anesthesia should be induced with Fentanyl (2.5 µg/kg) and Propofol (2.0 mg/kg) and maintained with Propofol (7 – 8 mg/kg/h reduced to 5 – 6 mg/kg/h after 15 minutes); if necessary, before placing stents additional Fentanyl (2 µg/kg) and Propofol (0.5 mg/kg) is administered.

### Bronchoscopic Equipment and Operative Technique

It is of paramount importance to work with a dedicated team of anesthesiologists and nurses familiar with the endoscopic maneuvers and the equipment required; this will facilitate the procedure especially in critical situations. Many different endoscopic techniques for palliation of airway obstruction have been described; they should all be considered along with the surgical options when assessing a patient with airway obstruction. In these situations bronchoscopy is essential in the evaluation process and CT virtual bronchoscopy should not be used as a substitute. Bronchoscopy in the critical patient should be performed only by an expert bronchoscopist; it allows the surgeon to define the extent, severity, and complexity of the stenosis. It also permits assessment of potential treatment modalities and directs bronchoscopic intervention. It should be performed by an endoscopist familiar both with interventional bronchology and the potential surgical options.

Both the flexible and rigid bronchoscopes should be available even if some endoscopists tend to favor either the former or the latter. Flexible fiberoptic bronchoscopy allows evaluation and diagnosis under local anesthesia as well as placement of expandable stents with the patient awake. However, rigid bronchoscopy provides a much wider spectrum of interventions; it has the disadvantage of requiring general anesthesia but allows one to quickly achieve a patent distal airway and adequately ventilate the patient, preserving oxygenation in critical situations. During rigid bronchoscopy therapeutic maneuvers can be immediately performed, such as vaporizing endoluminal lesions with laser and placing silicone or expandable metal stents. In case assessment and subsequent treatment of lesions located in the distal airway is required, the flexible bronchoscope can be inserted through the rigid barrel and advanced peripherally. It should always be stressed that even if fiberoptic bronchoscopy is planned as the first step, in critically ill patients it should be performed in the operating room, ready to proceed with the rigid bronchoscope if the clinical and anatomic situation requires it.

Flexible bronchoscopy is performed using an adult bronchoscope with a large working channel (2.8 to 3.2 mm) to allow adequate suction and delivery of laser probes, balloon dilators, and stent delivery devices. Larger stent delivery catheters should be introduced under fluoroscopy after placing external radiopaque markers.

Rigid bronchoscopy allows better and safer management of critical obstructions. We prefer the universal Dumon–Harrel rigid bronchoscope (EFER, La Ciotat, France) that comes in a variety of sizes and is designed with a multiport head allowing ventilation, suction with multiple catheters, and insertion of the laser probe and the telescope.

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The rigid bronchoscope is introduced under direct vision and is advanced until the obstruction is visualized. The use of telescopes connected to a video system greatly facilitates the procedure, also allowing image magnification. Lesions growing within the airway may be mechanically debrided or vaporized by laser (**Figure 5**). Extrinsic compressions should be gently dilated with the tip of the bronchoscope until the barrel can be advanced distally to gain a patent lumen and ventilate the patient. The use of rigid bronchoscopes that sequentially increase in diameter may facilitate this maneuver. Postintubation tracheal stenoses should be radially incised in three or four points before advancing the rigid bronchoscope to dilate it. Benign stenoses at the level of the main bronchi (after sleeve lobectomy, transplantation, radiotherapy, tuberculous infection) may pose different problems. The first dilation attempt is sometimes difficult if the stenosis is extremely tight and rigid, providing a large discrepancy between the diameter of the lumen and the caliber of the bronchoscope. In such situations balloon dilation is performed before forcing the rigid scope through the stenosis. In some cases we have successfully used old fashioned metal esophageal Souttar dilators that were rescued from the historical armamentarium of our endoscopy unit (**Figure 6**). If the tumor is located at the level of the carina and involves the distal trachea and both mainstem bronchi it is extremely important to quickly gain a viable airway and ventilate the patient. When the airway is patent and tumor extension has been carefully evaluated, a Y stent can be placed (**Figure 7**). Once an adequate airway caliber has been obtained the patency and stability of the lumen should be considered and any tendency for airway collapse requires stent placement. Stenting is also considered to prolong patency if an obstructing tumor is growing inside the airway

### Choice of Stent

Once an adequate caliber of the airway has been obtained stenting may be required for two reasons: 1) the airway tends to collapse or 2) to prolong the period of patency in case of malignant involvement. The final step is the assessment of the type and size of the stent to be placed. There are a number of stents currently available (**Table 2**) and each one shows advantages and disadvantages. Basically there are two groups of stents: silicone and metal stents. A selection of each category should be always available to optimize treatment and results.

The primary advantage of silicone stents is that they are easily adjustable and removable, and can be repositioned and changed as many times as required; with these stents there is no ingrowth and no reaction of the airway mucosa. The Dumon silicone stents (Novatech, Plan de Grasse, France) were specifically designed for the airway (**Figure 9**) [[10](http://www.ctsnet.org/sections/clinicalresources/thoracic/expert_tech-1.html#references)]. The cylindrical form provides a vault effect by which compressive forces are evenly distributed. Flexibility facilitates placement and removal, improves tolerance, and tends to preserve clearance of secretions. The studs on the outer surface of the stent prevent migration and reduce mucosal ischemia by limiting contact with the airway wall. A wide range of sizes and diameters are available (from 9 to 18 mm in external diameter and from 20 to 60 mm in length) so that stenting can be limited to the stenotic zone, encompassing only 0.5 cm above and below it; in fact, minimizing the length of the stent is a key factor in maintaining clearance of secretions and enhancing tolerance. The rims of each stent are polished to remove burrs and to reduce the risk of granuloma formation. Radiopaque Dumon stents are also available to improve visualization on chest x-ray. Obvious disadvantages of this type of stent are the need for rigid bronchoscopy for placement, along with some potential difficulties during deployment. A legitimate criticism is the smaller inner diameter due to the thicker wall of the stent and the potential for dislodgement and distortion. The loss of mucociliary clearance has a lower impact on secretion retention with the new generation stents. The Montgomery T tube (**Figure 10**) is still a useful stent and should be always considered for patients with a tracheostomy and a working larynx. Silicone Hood stents (Pembrooke, MA, USA) (**Figure 11**) have almost the same characteristics as the Dumon stents but have no studs on the outer surface.

In contrast, expandable metal stents can be easily delivered using a flexible bronchoscope under local anesthesia using fluoroscopy. These stents are extremely stable and migration is virtually impossible. The most recent generation of expandable stents (Wallstent and Ultraflex) conforms much better to the anatomy of the airway. Expandable stents may be covered (silicone rubber or polyurethane) or uncovered. Uncovered stents (**Figure 12**) are eventually incorporated within the airway wall with neoepithelization and resumption of mucociliary clearance. Covered stents (**Figure 13**) should be used in patients with malignant strictures when the tumor tends to grow within the airway. Uncovered stents allow also ventilation of lobar bronchi through the interstices of the metal mesh in case the airway needs to be stented above and below these orifices. However, these stents show some disadvantages: they are permanent since removal is extremely difficult, if not impossible; adjustment is difficult; fluoroscopy is required during placement; and granulations tend to grow at the level of the uncovered edges. If uncovered expandable stents are used to support neoplastic stenoses, they may erode the wall of the airway and the tumor may grow through the mesh. Last but not least, they are much more expensive than silicone stents. At our institution, the only indication for uncovered stents is airway malacia.

The Polyflex expandable stents (**Figure 14**) are made of a polyester mesh coated with silicone; they are self expandable and constrained within a delivery catheter. These stents don’t have uncovered edges and their potential advantages and disadvantages place them somewhere between the silicon and the expandable metal stents.

Freitag and colleagues extensively described the use of the Dynamic stent (**Figures 15, 16**) in patients with benign and malignant airway obstructions. This stent shows the potential advantage of having a flexible “membranous wall” able to squeeze down during coughing, facilitating mucous clearance. Placement of this stent is potentially more complicated but dedicated delivery grasping forceps have been designed to facilitate it (**Figure 17**). Results are promising for management of distal tracheal, carinal, and mainstem bronchial obstructions.

Given all the advantages and potential disadvantages of these two groups of stents, the optimum choice is determined by the anatomy of the lesion and the airway. The preferences and experience of the surgeon also plays a major role. There are some settings in which the morphology and position of the lesion (tortuous long strictures or lesions in proximity to lobar orifices) may be impossible to treat with silicone stents, and expandable stents provide the only remedy. Patients with airway malacia may require an expandable stent due to the difficulty of seating a silicone stent in the absence of a fixed stenosis.

We generally place a 14 to 16 mm (external diameter) silicone stent in the trachea and a 10 to 12 mm stent in the main bronchi. The experience of the surgeon greatly helps in choosing the correct size. The outer surface of the stent should adhere to the airway without pushing too much on the mucosa to avoid granulation formation. The correct length of the stent is selected by putting the tip of the rigid bronchoscope at the end of the stenosis and withdrawing it, measuring the distance at the level of the teeth. The stent should cover all the stenosis and 0.5 cm of normal airway at each end.

### Stent Insertion

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At the University of Rome “La Sapienza” we prefer silicone Dumon stents (**Figure 9**) for the vast majority of the lesions. We have placed expandable metal stents only when satisfactory placement of a silicone prosthesis could not be obtained or marked external compression produces distortion. (**Figure 18**) Silicone stents may be difficult to deploy. We routinely use the Dumon stent delivery system (EFER, La Ciotat, France). These stents are placed inside a delivery tube of the appropriate caliber based on the size of the rigid bronchoscope used for dilation and a plunger system is used to push it out of the introducer. Fine adjustments after stent deployment are performed with grasping forceps (**Figure 19**) under direct visualization.

There are also other techniques for silicone stent placement. The stent can be placed outside the rigid bronchoscope with an endotracheal tube inserted as a sheath over the proximal portion of the bronchoscope. The patient is then intubated with the bronchoscope–stent–pusher apparatus (**Figure 20**). The endotracheal tube prevents the stent from sliding upward during insertion of the bronchoscope. After placing the tip of the bronchoscope beyond the stenosis the rigid tube is gradually withdrawn while the external endotracheal tube is held in place, leaving the stent at the desired location.

A silicone stent can also be delivered through the lumen of the rigid bronchoscope, pushing it through the tube itself with the grasping forceps. With this technique the stent is usually deployed beyond the stenosis and needs to be pulled upward with forceps. Some larger stents (more that 16 mm or carinal Y stents) are placed through the vocal cords into the proximal airway using grasping forceps, and subsequently pushed in the correct position under direct control through the bronchoscope.

Expandable metallic stents have different delivery systems: the Wallstent and Ultraflex stent are contained within a delivery sheath; the Palmaz and Strecker stents need expansion over a balloon. Even if fluoroscopy guidance is recommended, simultaneous viewing through the rigid telescope or the flexible bronchoscope may contribute to improved accuracy of deployment. In some cases it is necessary to place multiple stents to optimize palliation.

### Management of Stent

There are no studies supporting any medical intervention after stent placement and each center has his own policy. We usually recommend immediate saline nebulization, adding steroids for the first three to four days. Antibiotic prophylaxis is administered for three days. It is extremely important to keep the patient well hydrated to reduce the thickness of secretions; this may not be easy in cachectic patients with advanced cancer. A chest x-ray is always performed after stent placement and fiberoptic bronchoscopy is usually performed within two to three weeks unless the patient shows symptoms requiring earlier endoscopic monitoring. Afterwards, bronchoscopy is performed according to the underlying disease, the clinical status of the patient, and the presence of symptoms (respiratory failure, cough, stridor, purulent secretions, etc).

## Tips & Pitfalls

* Before starting any endoscopic procedure, even if only an “evaluation” fiberoptic bronchoscopy is planned, have all the required tools ready available: rigid bronchoscope, laser, stents; inform the operating room personnel and the anesthetist.
* Work with a team of anesthetists and nurses familiar with operative endoscopy. It is better if they are always the same. The endoscopist / surgeon is responsible for solving all the potential problems, but he/she works much better if the entire team knows what to do.
* Keep in mind that there are oncologic patients with airway narrowing who are near the end of life. Sometimes there is no benefit in performing a difficult endoscopic procedure to give a patent airway to a patient who has exhausted all the available therapeutic resources and has no more strength to breath.
* Always keep different sizes and types of stents available, including at least one Y carinal stent. Remember that the Montgomery T tube is still useful and keep it in your armamentarium. When you use a stent be certain that it is immediately reordered so that one is readily available for future use. Keep informed of what you have or don’t have in your stent inventory.
* Do not rely upon an endoscopic examination performed by others unless there is a photograph available. If the endoscopy was not preformed recently, repeat it before planning treatment.
* Do not rely upon virtual bronchoscopy alone to plan an endoscopic procedure or to exclude the chance of surgery.
* Radiological imaging should be recent. Get a chest x-ray not more than one or two days before treatment.
* Always remember that surgical options are still the best treatment when technically feasible, according to the clinical status of the patient and the appropriate oncologic indications.

**SURFACTANT THERAPY**

* **Surfactant therapy has revolutionized neonatal respiratory care over the past two decades.**
* **Use have been tested in multicenter RCT**

**It is clear that prophylactic or rescue surfactant therapy to babies with or at risk of developing RDS reduces risk of neonatal death and pneumothorax**

* **The earlier in the course of RDS that surfactant is given the greater the chance of avoiding ventilation.**
* **Prophylaxis (within 15 min of birth) should be given to almost all babies <27 weeks’ gestation.**

**Prophylaxis should be considered for babies over 26 weeks but < 30 weeks’ gestation if intubation is needed in delivery suite or if the mother has not received prenatal steroids**

* **Early rescue surfactant should be given to untreated babies if there is evidence of RDS e.g. ↑ requirement for oxygen (A).**
* **In babies who require surfactant, use of the ‘‘INSURE’’ technique (INtubate – SUrfactant – Extubate to CPAP) has been shown in RCT trials to reduce the need for mechanical ventilation.**

**For babies on CPAP a second dose should be given if they are determined to need mechanical ventilation.**

* **Bolus instillation or fairly rapid instillation over one minute result in better distribution of surfactant**
* **Administration via a dual lumen ET tube without disconnection from mechanical ventilation is effective at reducing short-term side effects such as hypoxemia and bradycardia.**

**Surfactant Re-dosing**

* **There are 2 approaches to repeat dosing- rigid and more flexible re-dosing.**

**A 2nd & sometimes a 3rd dose should be given if there is ongoing evidence of RDS e.g. persistent oxygen requirement and need for mechanical ventilation or if over 50% oxygen is needed on CPAP at 6 cm H2O as this reduces pneumothorax and probably also mortality.**

**Surfactant Preparations**

* **There are several different types of surfactant preparation licensed for use in neonates with RDS including synthetic (protein-free) and natural (derived from animal lungs) surfactants**

**Natural surfactants should be used in preference to synthetic as they reduce pulmonary air leaks and mortality.**

**After Surfactant Treatment**

**Where possible, duration of mechanical ventilation should be shortened by immediate (or early) extubation to CPAP following surfactant administration provided the baby is otherwise stable.**

# HIGH-FREQUENCY VENTILATION

**High frequency ventilation** is a type of [mechanical ventilation](http://en.wikipedia.org/wiki/Mechanical_ventilation) which utilizes a respiratory rate greater than 4 times the normal value.[[1]](http://en.wikipedia.org/wiki/High-frequency_ventilation#cite_note-pmid13174467-1) (>150 (Vf) breaths per minute) and very small [tidal volumes](http://en.wikipedia.org/wiki/Tidal_volume).[[2]](http://en.wikipedia.org/wiki/High-frequency_ventilation#cite_note-krishan-2)[[3]](http://en.wikipedia.org/wiki/High-frequency_ventilation#cite_note-pmid2510975-3) High frequency ventilation is thought to reduce [ventilator-associated lung injury](http://en.wikipedia.org/wiki/Ventilator-associated_lung_injury) (VALI), especially in the context of [ARDS](http://en.wikipedia.org/wiki/ARDS) and [acute lung injury](http://en.wikipedia.org/wiki/Acute_lung_injury).[[2]](http://en.wikipedia.org/wiki/High-frequency_ventilation#cite_note-krishan-2) This is commonly referred to as **lung protective ventilation**.[[4]](http://en.wikipedia.org/wiki/High-frequency_ventilation#cite_note-pmid16507163-4) There are different flavors of **High frequency ventilation**.[[2]](http://en.wikipedia.org/wiki/High-frequency_ventilation#cite_note-krishan-2) Each type has its own unique advantages and disadvantages. The types of HFV are characterized by the delivery system and the type of exhalation phase.

High frequency ventilation may be used alone, or in combination with conventional mechanical ventilation. In general, those devices that need conventional mechanical ventilation do not produce the same lung protective effects as those that can operate without tidal breathing. Specifications and capabilities will vary depending on the device manufacturer.

## High frequency ventilation (passive)

### [[edit](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=2)]High frequency jet ventilation

Drawing of air movement in alveoli during jet ventilation, HFV-P

Inhaled nitric oxide (iNO) delivery with high-frequency jet ventilation

High frequency jet ventilation (HFJV) is provided by the [Bunnell](http://en.wikipedia.org/wiki/Bunnell_Incorporated%22%20%5Co%20%22Bunnell%20Incorporated) Life Pulse High-Frequency Ventilator. HFJV employs an endotracheal tube adaptor in place for the normal 15 mm ET tube adaptor. A high pressure "jet" of gas flows out of the adaptor and into the airway. This jet of gas occurs for a very brief duration, about 0.02 seconds, and at high frequency: 4-11 hertz. Tidal volumes ≤ 1 ml/Kg are used during HFJV. This combination of small tidal volumes delivered for very short periods of time creates the lowest possible distal airway and alveolar pressures produced by a mechanical ventilator. Exhalation is passive. Jet ventilators utilize various I:E ratios—between 1:1.1 and 1:12—to help achieve optimal exhalation. Conventional mechanical breaths are sometimes used to aid in reinflating the lung. Optimal PEEP is used to maintain alveolar inflation and promote ventilation-to-perfusion matching. Jet ventilation has been shown to reduce ventilator induced lung injury by as much as 20%. Usage of high frequency jet ventilation is recommended in neonates and adults with severe lung injury.[[5]](http://en.wikipedia.org/wiki/High-frequency_ventilation#cite_note-D._P._Schuster.2C_M._Klain_.26_J._V._Snyder_1982_625.E2.80.93630-5)

#### [[edit](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=3)]Indications for use

The Bunnell Life Pulse High-Frequency Ventilator is indicated for use in ventilating critically ill infants with [pulmonary interstitial emphysema](http://en.wikipedia.org/wiki/Pulmonary_interstitial_emphysema) (PIE). Infants studied ranged in birth weight from 750 to 3529 grams and in [gestation age](http://en.wikipedia.org/w/index.php?title=Gestation_age&action=edit&redlink=1) from 24 to 41 weeks.

The Bunnell Life Pulse High-Frequency Ventilator is also indicated for use in ventilating critically ill infants with [respiratory distress syndrome](http://en.wikipedia.org/wiki/Infant_respiratory_distress_syndrome) (RDS) complicated by pulmonary air leaks who are, in the opinion of their physicians, failing on [conventional ventilation](http://en.wikipedia.org/w/index.php?title=Conventional_ventilation&action=edit&redlink=1). Infants of this description studied ranged in birth weight from 600 to 3660 grams and in [gestational age](http://en.wikipedia.org/wiki/Gestational_age) from 24 to 38 weeks.

#### [[edit](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=4)]Adverse effects

The adverse side effects noted during the use of high-frequency ventilation include those commonly found during the use of conventional positive pressure ventilators. These adverse effects include:

* [Pneumothorax](http://en.wikipedia.org/wiki/Pneumothorax)
* [Pneumopericardium](http://en.wikipedia.org/wiki/Pneumopericardium)
* [Pneumoperitoneum](http://en.wikipedia.org/wiki/Pneumoperitoneum)
* [Pneumomediastinum](http://en.wikipedia.org/wiki/Pneumomediastinum)
* [Pulmonary interstitial emphysema](http://en.wikipedia.org/wiki/Pulmonary_interstitial_emphysema)
* [Intraventricular hemorrhage](http://en.wikipedia.org/wiki/Intraventricular_hemorrhage)
* [Necrotizing tracheobronchitis](http://en.wikipedia.org/w/index.php?title=Necrotizing_tracheobronchitis&action=edit&redlink=1)
* [Bronchopulmonary dysplasia](http://en.wikipedia.org/wiki/Bronchopulmonary_dysplasia)

#### [[edit](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=5)]Contraindications

High-frequency jet ventilation is contraindicated in patients requiring tracheal tubes smaller than 2.5 mm ID.

#### [[edit](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=6)]Settings and parameters

##### **[**[**edit**](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=7)**]**Peak inspiratory pressure (PIP)

The peak inspiratory pressure (PIP) window displays the average PIP. During startup a PIP sample is taken with every inhalation cycle and is averaged with all other samples taken over the most recent ten-second period. After regular operation begins, samples are averaged over the most recent twenty-second period.

##### **[**[**edit**](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=8)**]**ΔP (Delta P)

The value displayed in the ΔP (pressure difference) window represents the difference between the PIP value and the PEEP value.

##### **[**[**edit**](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=9)**]**Servo pressure

The servo pressure display indicates the amount of pressure the machine must generate internally in order to achieve the PIP appearing in the servo-display. Its value can range from 0—20 psi (0—137.9 [kPa](http://en.wikipedia.org/wiki/KPa%22%20%5Co%20%22KPa)). If the PIP sensed or approximated at the distal tip of the tracheal tube deviates from the desired PIP, the machine automatically generates more or less internal pressure in an attempt to compensate for the change. The servo-pressure display keeps the [operator](http://en.wikipedia.org/wiki/Respiratory_therapist) informed.

The servo display is a general clinical indicator of changes in the [compliance](http://en.wikipedia.org/wiki/Pulmonary_compliance) or [resistance](http://en.wikipedia.org/wiki/Airway_resistance) of the patient's lungs, as well as loss of lung volume due to tension [pneumothorax](http://en.wikipedia.org/wiki/Pneumothorax).

### [[edit](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=10)]High frequency percussive ventilation

**HFPV** — High frequency percussive ventilation combines HFV plus time cycled, pressure-limited controlled mechanical ventilation (i.e., pressure control ventilation, PCV).

### [[edit](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=11)]High frequency positive pressure ventilation

**HFPPV** — High frequency positive pressure ventilation is rarely used anymore, having been replaced by high frequency jet, oscillatory and percussive types of ventilation. HFPPV is delivered through the [endotracheal tube](http://en.wikipedia.org/wiki/Endotracheal_tube%22%20%5Co%20%22Endotracheal%20tube) using a conventional ventilator whose frequency is set near its upper limits. HFPV began to be used in selected centres in the 1980s. It is a hybrid of conventional [mechanical ventilation](http://en.wikipedia.org/wiki/Mechanical_ventilation) and high-frequency oscillatory ventilation. It has been used to salvage patients with persistent [hypoxemia](http://en.wikipedia.org/wiki/Hypoxemia) when on conventional mechanical ventilation or, in some cases, used as a primary modality of ventilatory support from the start.[[6]](http://en.wikipedia.org/wiki/High-frequency_ventilation#cite_note-pmid16860628-6)[[7]](http://en.wikipedia.org/wiki/High-frequency_ventilation#cite_note-pmid-7)

### [[edit](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=12)]High frequency flow interruption

**HFFI** — High Frequency Flow Interruption is similar to high frequency jet ventilation but the gas control mechanism is different. Frequently a rotating bar or ball with a small opening is placed in the path of a high pressure gas. As the bar or ball rotates and the opening lines-up with the gas flow, a small, brief pulse of gas is allowed to enter the airway. Frequencies for HFFI are typically limited to maximum of about 15 hertz.

## [[edit](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=13)]High frequency ventilation (active)

**High frequency ventilation (active)** — HFV-A is notable for the active exhalation mechanic included. Active exhalation means a negative pressure is applied to force volume out of the lungs.

### [[edit](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=14)]High frequency oscillatory ventilation

Sensormedics 3100a Oscillatory ventilator

Details of a patient circuit

High frequency oscillatory ventilation was first described in 1972[[8]](http://en.wikipedia.org/wiki/High-frequency_ventilation#cite_note-pmid5045565-8) and is used in neonates and adult patient populations to reduce lung injury, or to prevent further lung injury.[[9]](http://en.wikipedia.org/wiki/High-frequency_ventilation#cite_note-9) HFOV is characterized by high respiratory rates between 3.5 to 15 [hertz](http://en.wikipedia.org/wiki/Hertz) (210 - 900 breaths per minute) and having both inhalation and exhalation maintained by active pressures. The rates used vary widely depending upon patient size, age, and disease process. In HFOV the pressure oscillates around the constant distending pressure (equivalent to mean airway pressure [MAP]) which in effect is the same as [positive end-expiratory pressure](http://en.wikipedia.org/wiki/Positive_end-expiratory_pressure) (PEEP). Thus gas is pushed into the lung during inspiration, and then pulled out during expiration. HFOV generates very low tidal volumes that are generally less than the dead space of the lung. Tidal volume is dependent on endotracheal tube size, power and frequency. Different mechanisms (direct bulk flow - convective, Taylorian dispersion, Pendelluft effect, asymmetrical velocity profiles, cardiogenic mixing and molecular diffusion) of gas transfer are believed to come into play in HFOV compared to normal mechanical ventilation. It is often used in patients who have refractory hypoxemia that cannot be corrected by normal mechanical ventilation such as is the case in the following disease processes: severe ARDS, ALI and other oxygenation diffusion issues. In some neonatal patients HFOV may be used as the first-line ventilator due to the high susceptibility of the premature infant to lung injury from conventional ventilation.

### [[edit](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=15)]Breath delivery

The vibrations are created by an electromagnetic valve that controls a piston. The resulting vibrations are similar to those produced by a stereo speaker. The height of the vibrational wave is the amplitude. Higher amplitudes create greater pressure fluctuations which move more gas with each vibration. The number of vibrations per minute is the frequency. One Hertz equals 60 cycles per minute. The higher amplitudes at lower frequencies will cause the greatest fluctuation in pressure and move the most gas.

Altering the % inspiratory time (T%i) changes the proportion of the time in which the vibration or sound wave is above the baseline versus below it. Increasing the % Inspiratory Time will also increase the volume of gas moved or tidal volume. Decreasing the frequency, increasing the amplitude, and increasing the % inspiratory time will all increase tidal volume and eliminate CO2. Increasing the tidal volume will also tend to increase the mean airway pressure.

#### [[edit](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=16)]Settings and measurements

##### **[**[**edit**](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=17)**]**Bias flow

The bias flow controls and indicates the rate of continuous flow of humidified blended gas through the patient circuit. The control knob is a 15-turn pneumatic valve which increases flow as it is turned.

##### **[**[**edit**](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=18)**]**Mean pressure adjust

The mean pressure adjust setting adjusts the mean airway pressure (PAW) by controlling the resistance of the airway pressure control valve. The mean airway pressure will change and requires the mean pressure adjust to be adjusted when the following settings are changed:

* Frequency (Hertz)
* % Inspiratory time
* Power and Δp change
* Piston centering

During high frequency oscillatory ventilation (HFOV), PAW is the primary variable affecting oxygenation and is set independent of other variables on the oscillator. Because distal airway pressure changes during HFOV are minimal,[[10]](http://en.wikipedia.org/wiki/High-frequency_ventilation#cite_note-pmid2235135-10)[[11]](http://en.wikipedia.org/wiki/High-frequency_ventilation#cite_note-pmid18996228-11) the PAW during HFOV can be viewed in a manner similar to the [PEEP](http://en.wikipedia.org/w/index.php?title=Peak_end-expiratory_pressure&action=edit&redlink=1) level in conventional ventilation.[[12]](http://en.wikipedia.org/wiki/High-frequency_ventilation#cite_note-pmid22096349-12) The optimal PAW can be considered as a compromise between maximal lung recruitment and minimal overdistention.

##### **[**[**edit**](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=19)**]**Mean pressure limit

Drawing of air movement during high frequency oscillation ventilation

The mean pressure limit controls the limit above which proximal PAW cannot be increased by setting the control pressure of the pressure limit valve. The mean pressure limit range is 10-45 cmH2O.

##### **[**[**edit**](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=20)**]**ΔP and amplitude

Tidal volume versus power setting

The power setting is set as amplitude to establish a measured change of pressure (ΔP). Amplitude/Power is a setting which determines the amount of power that is driving the oscillator piston forward and backward resulting in an air volume ([tidal volume](http://en.wikipedia.org/wiki/Tidal_volume)) displacement. The effect of the amplitude on the ΔP that it is changed by the displacement of the oscillator piston and hence the oscillatory pressure (ΔP). The power setting interacts with PAW conditions existing within the patient circuit to produce the resulting ΔP.

##### **[**[**edit**](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=21)**]** % Inspiratory time

The percent of inspiratory time is a setting which determines the percent of cycle time the piston is traveling toward (or at its final inspiratory position). The inspiratory percent range is 30—50%.

##### **[**[**edit**](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=22)**]**Frequency

Tidal volume versus frequency in Hertz

The frequency setting is measured in hertz (hz). The control knob is a 10-turn clockwise-increasing potentiometer covering a range of 3 Hz to 15 Hz. The set frequency is displayed on a digital meter on the face of the ventilator. One Hertz is (-/+5%) equal to 1 breath per second, or 60 breaths per minute (e.g, 10 Hz = 600 breaths per minute). Changes in frequency are inversely proportional to the amplitude and thus delivered [tidal volume](http://en.wikipedia.org/wiki/Tidal_volume).

**Breaths per minute (f)**

##### **[**[**edit**](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=23)**]**Oscillation trough pressure

Oscillation trough pressure is the pressure existing within the HFOV circuit during the ventilators negative deflection.

## [[edit](http://en.wikipedia.org/w/index.php?title=High-frequency_ventilation&action=edit&section=24)]Adverse effects

The adverse side effects noted during the use of high-frequency ventilation include those commonly found during the use of conventional positive pressure ventilators. These adverse effects include:

* [Pneumothorax](http://en.wikipedia.org/wiki/Pneumothorax)
* [Pneumopericardium](http://en.wikipedia.org/wiki/Pneumopericardium)
* [Pneumoperitoneum](http://en.wikipedia.org/wiki/Pneumoperitoneum)
* [Pneumomediastinum](http://en.wikipedia.org/wiki/Pneumomediastinum)
* [Pulmonary interstitial emphysema](http://en.wikipedia.org/wiki/Pulmonary_interstitial_emphysema)
* [Intraventricular hemorrhage](http://en.wikipedia.org/wiki/Intraventricular_hemorrhage)
* [Necrotizing tracheobronchitis](http://en.wikipedia.org/w/index.php?title=Necrotizing_tracheobronchitis&action=edit&redlink=1)
* [Bronchopulmonary dysplasia](http://en.wikipedia.org/wiki/Bronchopulmonary_dysplasia)

# Cryotherapy

**Cryotherapy** is the local or general use of low temperatures in medical therapy. Cryotherapy is used to treat a variety of benign and malignant [lesions](http://en.wikipedia.org/wiki/Lesion).[[1]](http://en.wikipedia.org/wiki/Cryotherapy#cite_note-1) The term "cryotherapy" comes from the Greek *cryo* (κρυο) meaning *cold*, and *therapy* (θεραπεια) meaning *cure*. Cryotherapy has been used as early as the seventeenth century.

Its goal is to decrease [cellular metabolism](http://en.wikipedia.org/wiki/Cellular_metabolism), increase cellular survival, decrease [inflammation](http://en.wikipedia.org/wiki/Inflammation), decrease [pain](http://en.wikipedia.org/wiki/Pain) and spasm, promote [vasoconstriction](http://en.wikipedia.org/wiki/Vasoconstriction), and when using extreme temperatures, to destroy cells by crystallizing the [cytosol](http://en.wikipedia.org/wiki/Cytosol%22%20%5Co%20%22Cytosol). The most prominent use of the term refers to the surgical treatment, specifically known as [cryosurgery](http://en.wikipedia.org/wiki/Cryosurgery). Other therapies that use the term are cryogenic chamber therapy and ice pack therapy.

## Hyperbaric gaseous cryotherapy

In 1993, the company [Cryonic Medical](http://www.cryoinic-medical.com/)[[2]](http://en.wikipedia.org/wiki/Cryotherapy#cite_note-2) developed the hyperbaric gaseous cryotherapy also called NeuroCryoStimulation or NCS that can immediately relieve pain by acting on four physiological effects :

1. Painkiller
2. Vasomotor
3. Anti-inflammatory
4. Muscle relaxation

This technique, practiced by some doctors, physiotherapists and veterinarians consists in applying for a short time on the skin up to the painful area, [carbon dioxide](http://en.wikipedia.org/wiki/Carbon_dioxide) at -78°C with a pressure of 50 bars and a frequency of 400 Hz. Sessions can be repeated at will. Unlike ice packs, the usage of carbon dioxide does not produce pain. Even if not as dangerous as liquid nitrogen used in cryosurgery, the low temperature could cause burns. This risk can be mitigated by using a limited volume of gas (80 gr) and by cutting the power supply of device as soon as the temperature of the skin reaches 2°C.

## Cryosurgery

Cryosurgery is the application of extreme cold to destroy abnormal or diseased tissue. Cryotherapy is used to treat a number of diseases and disorders, most especially skin conditions like [warts](http://en.wikipedia.org/wiki/Warts), [moles](http://en.wikipedia.org/wiki/Melanocytic_nevus), [skin tags](http://en.wikipedia.org/wiki/Skin_tags) and [solar keratoses](http://en.wikipedia.org/wiki/Solar_keratoses). [Liquid nitrogen](http://en.wikipedia.org/wiki/Liquid_nitrogen) is usually used to freeze the tissues at the cellular level. The procedure is used often because of its efficacy and low rates of side effects.

## Hilotherapy

Hilotherapy is a treatment, which allows the controlled application of cooling to selected areas of the face and body. A cuff is wrapped around the traumatized area, which is connected to the device that allows the traumatized area to be cooled at a specific temperature. The difference between [Hilotherapy](http://hilotherapy.co.uk/) and other cryotherapy approaches is the range of temperature and the constant application. By controlling the temperature between 10°C and 20°C, the typical benefits from cryotherapy occur, such as immediate [vasoconstriction](http://en.wikipedia.org/wiki/Vasoconstriction%22%20%5Co%20%22Vasoconstriction)with reflexive [vasodilation](http://en.wikipedia.org/wiki/Vasodilation%22%20%5Co%20%22Vasodilation), decreased local [metabolism](http://en.wikipedia.org/wiki/Metabolism) and [enzymatic](http://en.wikipedia.org/wiki/Enzymatic) activity, and decreased oxygen demand. However, by not reducing below 10°C, the [lymphatic drainage](http://en.wikipedia.org/wiki/Lymphatic_drainage) is not disturbed, nor is the creation of [fibroblasts](http://en.wikipedia.org/wiki/Fibroblasts) and the [microcirculation](http://en.wikipedia.org/wiki/Microcirculation), all of which cease to function during the normal application of ICE and when the tissue falls below the 10°C. Hilotherapy is commonly used for the recovery of[orthopedic surgery](http://en.wikipedia.org/wiki/Orthopedic_surgery), [plastic surgery](http://en.wikipedia.org/wiki/Plastic_surgery) and [Oral and maxillofacial surgery](http://en.wikipedia.org/wiki/Oral_and_maxillofacial_surgery).

## Ice pack therapy

Ice pack therapy is a treatment of cold temperatures to an injured area of the body. An [ice pack](http://en.wikipedia.org/wiki/Ice_pack) is placed over an injured area and is intended to absorb heat of a closed traumatic or edematous injury by using conduction to transfer thermal energy. The physiologic effects of cold application include immediate [vasoconstriction](http://en.wikipedia.org/wiki/Vasoconstriction) with reflexive [vasodilation](http://en.wikipedia.org/wiki/Vasodilation%22%20%5Co%20%22Vasodilation), decreased local [metabolism](http://en.wikipedia.org/wiki/Metabolism) and [enzymatic](http://en.wikipedia.org/wiki/Enzymatic%22%20%5Co%20%22Enzymatic)activity, and decreased oxygen demand. Cold decreases muscle [spindle fiber](http://en.wikipedia.org/wiki/Spindle_fiber) activity and slows nerve conduction velocity, therefore it is often used to decrease spasticity and muscle guarding. It is commonly used to alleviate the pain of minor injuries.

## Cryogenic chamber therapy

Cryo therapy patients during preparation of treatment of ca. 3 minutes

According to *Costello et al*,[[3]](http://en.wikipedia.org/wiki/Cryotherapy#cite_note-3) a relatively new modality of cryotherapy, called Whole Body Cryotherapy (WBC), is currently being offered by clinicians as an alternative to cold water immersion or ice packs. Administered through the use of a cryogenic chamber, WBC is a treatment whereby the patient is placed in a [cryogenic](http://en.wikipedia.org/wiki/Cryogenics) chamber for a short duration (i.e. no more than three minutes, which is comparable to [ice swimming](http://en.wikipedia.org/wiki/Ice_swimming)), and if used properly, will not destroy tissue. Whole body cryotherapy originated in Japan in 1978. However, it was a group of Polish scientists who took the idea and made whole body cryotherapy the physical therapy it is today. The Olympic rehabilitation centre in Spala, Poland opened in May 2000 and has been used as a training and injury rehabilitation centre for many sporting bodies.

The chamber is cooled, typically with [liquid nitrogen](http://en.wikipedia.org/wiki/Liquid_nitrogen), usually to a temperature of −120 °C (−184 °F)—although temperatures of −140 °C(−220 °F) or even −160 °C (−256 °F) have been used.[[4]](http://en.wikipedia.org/wiki/Cryotherapy#cite_note-Warburton-4) The patient is protected from acute frostbite with socks, gloves and mouth and ear protection, but in addition to that, wears nothing but a bathing suit. The patient spends a few minutes in the chamber. During treatment the average skin temperature drops to 12 °C (54 °F), while the coldest skin temperature can be 5 °C (41 °F). The core body temperature remains unchanged during the treatment, however it may drop slightly afterwards. Therapy triggers the release of [endorphins](http://en.wikipedia.org/wiki/Endorphin%22%20%5Co%20%22Endorphin)which induce [analgesia](http://en.wikipedia.org/wiki/Analgesia) (immediate pain relief).[*[citation needed](http://en.wikipedia.org/wiki/Wikipedia%3ACitation_needed%22%20%5Co%20%22Wikipedia%3ACitation%20needed)*]

Patients report that the experience is invigorating and improves a variety of conditions such as psychological stress, insomnia,[rheumatism](http://en.wikipedia.org/wiki/Rheumatism), muscle and joint pain, [fibromyalgia](http://en.wikipedia.org/wiki/Fibromyalgia), [itching](http://en.wikipedia.org/wiki/Itching), and [psoriasis](http://en.wikipedia.org/wiki/Psoriasis).[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia%3ACitation_needed)] The immediate effect of skin cooling and analgesia lasts for 5 minutes, but the release of endorphins can have a lasting effect, where the pains and signs of inflammation as found in blood tests remain suppressed for weeks.[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia%3ACitation_needed)] The effects of extreme cold and endorphin release are scientifically studied. Curiously, some patients compare the feeling to [sauna](http://en.wikipedia.org/wiki/Sauna) at 110 °C (230 °F).[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia%3ACitation_needed)] [Wales rugby union international](http://en.wikipedia.org/wiki/Wales_national_rugby_union_team) [Sam Warburton](http://en.wikipedia.org/wiki/Sam_Warburton), who along with his teammates used the Spala facilities whilst training for the [2011 Rugby World Cup](http://en.wikipedia.org/wiki/2011_Rugby_World_Cup), has dubbed the chambers "evil saunas", but added:

"I'd be lying if I didn't say it was a pretty savage experience, but the other side of the coin is that it is definitely working and allowing us to train in a way that would be impossible under normal conditions."[[4]](http://en.wikipedia.org/wiki/Cryotherapy#cite_note-Warburton-4)

## [[edit](http://en.wikipedia.org/w/index.php?title=Cryotherapy&action=edit&section=6)]Cryotherapy and headaches

A study published in the September 2000 edition of the Archives of Family Medicine showed that a combination of pressure and cold temperatures can successfully mitigate[headache](http://en.wikipedia.org/wiki/Headach)-related pain and also decrease the duration of a headache.[[5]](http://en.wikipedia.org/wiki/Cryotherapy#cite_note-5) Eighty-seven percent of participants (p=.004) said that the combination of pressure as well as temperature therapy was "optimally effective"; 13% said that the temperature therapy was "moderately effective". Many products exist that provide temperature therapy, many times cryotherapy, to combat headaches.