Clinical Experience of Zhao’s Artificial Trachea

Wei Zhao¹, Li-Xin Tian², Xiao-Rui Zhou², Feng-Rui Zhao²
¹Department of Anesthesia, China-Japan Friendship Hospital, Beijing 100029, China
²Department of Thoracic Surgery, Beijing Jiangong Hospital, Beijing 100054, China
³Department of Anesthesia, First Hospital of Tsinghua University, Beijing 100016, China

Key words: Reconstruction; Trachea Resection; Zhao’s Artificial Trachea

Clinical Experience

The practice of artificial tracheal prosthesis has been a major challenge to the entire surgical field worldwide until now. The previously applied prosthesis is “inner stent” type, which is unable to heal biologically with native trachea. The newly developed design, the Zhao’s artificial trachea, uses a memory alloy mesh combined with traditional operation procedures. Following a 2-year experimental period, the device has been applied to seven patients with satisfying results. We believe this to be a successful artificial trachea that is capable of complete biologically healing with the native trachea. No rejection, infection, or major complications were present in the seven patients, and the Zhao’s artificial trachea may be considered a real part of the trachea.

Clinical Application and Typical Cases

Seven consecutive cases of tracheal resection and reconstruction with Zhao’s artificial trachea (6 male and 1 female; 3 with malignant and 4 with benign diseases; aged 14–48 years) were completed between the year 2002 and 2004. All the patients were informed of the procedure and completed consent forms. In all instances, the patients exhibited normal physical examination and laboratory tests except for tracheal obstruction. No rejection, infection, or major complications were present in the seven patients, and the Zhao’s artificial trachea may be considered a real part of the trachea.

During the operation, great care was taken to avoid damaging blood supply in the muscle pedicle. The artificial trachea was anastomosed without tension, kink, or rotation. For the first patient, a tracheotomy was made to prevent edema of the artificial trachea below the lower anastomosis. In the remaining 6 cases, the procedures were performed without preventive tracheotomy. The length of the resected trachea was 5.0–8.0 cm and the length of the artificial trachea was 2.5–4.5 cm. However, the anastomosis was tension-free without difficulties, resulting in no need for the chin to sternum suturing and corresponding neck over-flexion. Therefore, the postoperative quality of life for the patients was relatively good.

Typical case 1
A 48-year-old female patient suffered from tracheal carcinoid tumor for 6 years and received laser treatment many times. However, recurrence occurred with increased shortness of breath. The tumor located in the upper airway, started 2 cm below the vocal cord, obstructed over 80% tracheal lumen, invaded more than 4/5 circle of the tracheal wall, expended downward along the tracheal wall for more than 4.5 cm, and pressed to nearby structure [Figure 1a]. The patient was unable to lie down due to shortness of breath and stridor, although her oxygen saturation and blood gas, laboratory tests including liver and kidney functions all indicated normal. Also, electrocardiography was normal, and abdominal ultrasound examination showed no abnormalities.

The first stage of the operation was carried out on January 27, 2002 under local anesthesia. Apnea occurred when the patient lay down on the operating table for intubation due to severe stridor indicated by arterial oxygen saturation (SaO₂) <70%, heart rate >150 beats/min, and blood pressure 180/110 mmHg (1 mmHg = 0.133 kPa). To move forward,
proved to be uneventful. On postoperative day 4, drainage of the lower anastomosis was made. Postoperative recovery was good, and therefore, the artificial trachea inevitably is infected. Eventually, the artificial trachea separates with patient's native trachea. Bronchoscopy demonstrated that upper and lower anastomosis was normal; the inner sides of native and artificial trachea were smooth and demonstrated normal color. There was one stitch that showed a tiny granulation in the lower anastomosis [Figure 1b]. All laboratory tests were normal. Unfortunately, the patient died from a pulmonary embolism 1 year later without experiencing any recurrent disease or any precursory symptom.

Typical case 2
A 37-year-old male patient who was a coal mine worker received a life-saving tracheotomy as the result of an accident, 3 years before being admitted to our hospital. Later, trachea lumen above the tracheotomy closed from granulation [Figure 1c] that resulted in a lost voice. Tracheal reconstruction was undertaken on December 17, 2004. A 2.5-cm Zhao’s artificial trachea was used. Ten years later, he received a check-up, it was found that the artificial trachea was securely in place and well open by X-ray examination. Bronchoscopic examination showed that the artificial trachea healed very well with native trachea. Close to the upper anastomosis, a small area of the trachea was visible through the very thin covering of skin. No inflammatory changes or adhering secretions were found. The trachea wall surface color appeared normal with both the upper and lower anastomoses of skin plus mucous membrane unable to be differentiated by the naked eye [Figure 1d]. He has lived a normal life as a labor worker for more than 10 years since the tracheal reconstruction.

**DISCUSSION**
Long-segment tracheal replacement remains a major dilemma to surgeons worldwide. Primary anastomosis of trachea after resection of a long-segment around 6 cm is extremely difficult. Tracheal replacement could be done by tracheal transplantation and artificial trachea; however, transplantation is still in the experimental stage and far from clinical use. Artificial trachea such as Neville is only a type of “stent” and around this stent, infection exists.

In reality, a shortfall is that the shape of an artificial trachea should be tube-like design, and this is one of the most important factors for its failure. This means there is no possibility to coat the inside completely with living tissue and, therefore, the artificial trachea inevitably is infected. Eventually, the artificial trachea separates with patient’s native trachea and tissues, becoming only a “stent” or a “windpipe.” Conversely, reconstruction of blood supply for an artificial trachea is still impossible.

---

**Figure 1:**
(a) The tracheal tumor obstructed almost all the lumen of the trachea and pressed on the nearby structure preoperatively. (b) The lumen was well open, and the skin of the artificial tracheal was healed with the membrane of the native trachea postoperatively. (c) Tracheal lumen above the tracheotomy closed completely preoperatively. (d) The lumen of the trachea opened well after 10 years postoperatively (a small area of alloy mesh was visible through the thin skin).

---

The patient leaned on 45° angle and the operation continued under local anesthesia. An incision was made above and parallel to the left clavicle. Dissecting beneath the skin, a 7.5 cm × 4.5 cm pouch was made, the preshaped memory alloy mesh was placed into the pouch, and the incision closed. The second stage of the operation was completed on April 18, 2002. A reverse “L” shape skin incision was made, the trachea was transected below the tumor, and a tracheal tube was inserted into the distal trachea to maintain ventilation and anesthesia. The tumor was dissected outside, the recurrent laryngeal nerve was preserved and protected, and the upper trachea 0.5 cm above the tumor was transected. A 6-cm tracheal segment including tumor was removed. Then in preparation for the artificial trachea, a rectangular incision along ridges of the metal mesh was made. Dissection was carried out beneath the platysma muscle; the second third was kept intact to preserve good blood supply. The “sandwich” flap (inner layer comprising skin, middle layer of metal mesh, and outer layer of platysma muscle) was curved upward to form a tube shape, and then the ridges of the tube were sutured together with 5 stainless steel wires in whole thick interrupted style. Subcutaneous tissue and the platysma muscle were secured to prevent air leakage. Sternoclidomastoid muscle was cut off from the mastoid, further dissected along with the muscle until the end of the sternum, so that the muscle would become a pedicle with blood supply to the artificial trachea. Then, the “sandwich” pedicle artificial trachea was placed into tracheal bed beneath sternothyroid muscle. Next, the upper and lower tracheal trunks were anastomosed with the artificial trachea by interrupted sutures using Vicryl 3-0 suture. Before closing the incision, a tracheotomy one cartilage ring beneath the lower anastomosis was made. Postoperative recovery proved to be uneventful. On postoperative day 4, drainage was stopped; and on postoperative day 15, the tracheotomy tube was removed. The patient was subsequently discharged from hospital on postoperative day 18.

One month later, the patient was completely capable to complete regular tasks as a farmer working in the fields. During the 3-month follow-up, X-ray investigation showed that the artificial trachea had become a part of the recipient’s trachea in good position, and its diameter was almost equivalent to the native trachea. Bronchoscopy demonstrated that upper and lower anastomosis was normal; the inner sides of native and artificial trachea were smooth and demonstrated normal color. There was one stitch that showed a tiny granulation in the lower anastomosis [Figure 1b]. All laboratory tests were normal. Unfortunately, the patient died from a pulmonary embolism 1 year later without experiencing any recurrent disease or any precursory symptom.
Zhao’s artificial trachea approaches the issues from a completely different design perspective. Instead of creating a tube shape, we use an alloy mesh and a two-stage operation to make an artificial trachea. After the alloy mesh has been embedded in a skin pouch for 3 weeks, subcutaneous tissue completely healed with the skin through the mesh. Then, during the second stage, using this rectangular “sandwich” skin muscle pedicle flap, we made a pedicle tube and created an artificial trachea. Skin on the inside bonds with the upper and lower tracheal mucous membrane, subcutaneous tissue, and platysma muscle bonds with the surrounding tracheal tissue. The memory alloy mesh is totally sealed within living tissue with its extra-strong elasticity without antigenicity but having very good compatibility to human tissue. Thus, it becomes a real artificial trachea, performing almost all the function of a human trachea except for cilium and secretion.

Ten years after the tracheal reconstruction, patients with malignant diseases died from other reasons independent of the functioning of the artificial trachea itself while patients with benign diseases still live normal life without major complications. All of the artificial tracheas were completely healed with the native trachea and functioning normally. This demonstrates that this type of artificial trachea is suitable for patients who require long-segment tracheal resection and reconstruction. In addition, it gives patients the better quality of life than any prior tracheal prostheses procedures that have been applied in the field of tracheal surgery.[2,3]

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References
1. Zhao F, Zhang Y, Liu S, Yu J. Artificial trachea reconstruction with two-stage approach using memory-alloy mesh. Chin Med J 2003;116:1949-51.
2. Zhao FR, Zhang YH, Yang JL, Tian LX, Huang Y. Long-term results of Zhao’s artificial trachea (in Chinese). Chin J Thorac Cardiovasc Surg 2008;24:220-2. doi: 10.3760/cma.j.issn.1001-4497.2008.04.002.
3. Zhao FR, Chen WS, Hao YB, Zhao YF, Li YM, Ma ZD. Experimental study of type-II Zhao’s artificial trachea (in Chinese). Chin J Thorac Cardiovasc Surg 2008;24:224-6. doi: 10.3760/cma.j.is sn.1001-4497.2008.04.004.