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Stent Treatment of Inferior-Vena-Cava Compression in an Ovine with a Total Artificial Heart

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Abstract

Although current continuous-flow total artificial hearts (CFTAHs) are much smaller than previous models, venous kinking may still occur after device implantation, especially in smaller animals. By inserting a self-expanding stent at the site of venous narrowing in a sheep model implanted with a CFTAH, we were able to restore the normal venous geometry and dramatically increase the CFTAH output. Because this percutaneous approach avoids the challenges associated with reoperation in these cases, it may be useful to other CFTAH investigators.

Keywords

total artificial heart; continuous flow; venous kinking; stent implantation; ovine studies

Introduction

Implantation of a total artificial heart (TAH) is challenging due to the large size of the device and the potential for compression or kinking of the superior vena cava (SVC), inferior vena cava (IVC), or pulmonary veins. In hopes of mitigating these challenges, we have recently focused our efforts on developing a smaller, simpler, continuous-flow TAH (CFTAH), utilizing some of the advances in continuous-flow pumps that have been made over the last several years. Despite the much smaller size of the current CFTAH, it is still possible to see venous kinking after implantation. We have devised a percutaneous method of addressing such kinking that avoids the challenges associated with reoperation. By implanting an appropriately sized nitinol stent at the site of venous narrowing, we have been able to improve the geometry and restore TAH function. In this brief report, we describe successful implementation of this strategy in a sheep implanted with a CFTAH.

Operative Technique

After removing the heart of a 72-kg Suffolk sheep, we implanted a CFTAH comprising 2 axial-flow pumps (MicroMed, Houston, Texas) by means of a technique that we have previously described (1). The CFTAH is configured with pressure lines integrated into each pump inflow and Doppler flow probes integrated into each pump outflow to allow systemic and pulmonary pump performance to be closely monitored. Postoperatively, the sheep was transported to the intensive care unit in stable condition. However, the maximal CFTAH

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output was 7 L/min despite our attempts to increase flow by increasing the pump speed. The CFTAH used in this case allows systemic and pulmonary pump inlet pressures to be monitored at the pump inlet. The inlet pressures remained low despite aggressive volume administration. The presumed diagnosis of inflow obstruction of one or both pumps was confirmed at fluoroscopic examination, where contrast-enhanced images showed significant extrinsic compression and kinking of the IVC at its junction with the right atrial remnant. To treat this problem, we inserted a self-expanding stent (Boston Scientific, Natick, Massachusetts) through the jugular vein and positioned the device at the point of narrowing. To prevent migration of the stent due to undersizing, we used a 24-mm stent on the basis of quantitative analysis of the vessel, including measurement of the distal and proximal vena cava and the extrinsically compressed area. The stent, once expanded, was wedged firmly in position. After stent deployment, unobstructed geometry was restored, and CFTAH output quickly increased to more than 10 L/min. On postoperative day 5, the sheep was humanely euthanized due to its inability to stand. At necropsy, the stent was in a good position, without thrombus, and the diagnosis of extrinsic compression by the CFTAH was confirmed.

Comments

In 1980, Golding and associates (2) were the first to establish parameters for adequate TAH flow in chronic animal models. The current accepted value is 125 to 135 mL/kg/min, and the continuous-flow TAH that we designed can generally perform within this range. We were concerned that we could not achieve this level of support, but we were even more concerned about our inability to increase the right-sided TAH's reservoir pressure despite aggressive volume administration. We can generally obtain a wide range of CFTAH output by increasing the left and right pump speed and administering volume. The preload and afterload sensitivity of our device has been well characterized. It was the lack of preload sensitivity in this animal that suggested a fixed obstruction to venous return. Because the pump flow did not increase with increasing pump speed despite aggressive volume administration, inflow obstruction was suspected. The culprit was found to be a kink in the IVC, which resulted from external compression by the pump's rigid atrial cuff and was easily treated by stent placement. One reason why stent placement was successful in this case is that it involved extrinsic compression of only one aspect of the IVC. In cases where the IVC is circumferentially compressed, stent placement may be less effective in reducing obstruction.

It is possible that a twisted IVC might be treated with stent placement to mitigate obstruction, but this is only speculation. The radiologic appearance of an extrinsically compressed IVC is different from that of a twisted IVC. In the event that a twist is suspected, stenting could perhaps be attempted, but operative revision might be necessary.

In our experience with 45 animals (calves and sheep) implanted with various iterations of a continuous-flow total artificial heart, this has been the only documented case of IVC compression to date. The follow-up period was limited, but the necropsy showed no stent migration. Extrinsic compression of the IVC after TAH implantation is such an infrequent complication that it is unlikely to occur often enough for us to generate more experience with it in the near future. Nevertheless, stent implantation worked so well to mitigate the obstruction in our case that we believe our experience may be valuable to other researchers if they encounter a similar situation.

In summary, in cases involving extrinsic compression of the SVC or IVC after implantation of a TAH, percutaneous placement of a self-expanding stent may provide a quick, safe alternative to surgical revision. In our case, the stent restored the normal geometry and

dramatically increased the CFTAH output. This approach may someday provide a valuable option for TAH patients who develop similar problems.

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References

1. Frazier OH, Cohn WE, Tuzun E, Winkler JA, Gregoric ID. Continuous-flow total artificial heart supports long-term survival of a calf. *Tex Heart Inst J*. 2009; 36:568–74. [PubMed: 20069083]
2. Golding LR, Jacobs G, Murakami T, Takatani S, Valdes F, Harasaki H, Nose Y. Chronic nonpulsatile blood flow in an alive, awake animal 34-day survival. *Trans Am Soc Artif Intern Organs*. 1980; 26:251–5. [PubMed: 7245493]

Figure 1. Venogram, with contrast injection into the inferior vena cava, showing two consecutive 11.6-mm (single arrow) and 6.3-mm (double arrows) areas of stenosis due to compression by the left atrial cuff of a total artificial heart.

Figure 2.
Venogram obtained after stent placement, showing complete relief of the inferior vena cava stenosis.