



Total artificial heart and the hepatobiliary-GI systems

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Introduction

As total artificial heart (TAH) replacement therapy is one of the few durable options for biventricular support and for complex cardiac conditions in the critically ill, it remains imperative that we understand the implications of this therapy on end-organ systems. In particular, the gastrointestinal (GI) and hepatobiliary systems incur unique effects after TAH implantation. Analysis of the Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) registry revealed that approximately 20% of patients had an episode of major GI bleeding within the first 6 months post-implantation. This is in comparison to 15% and 19% of patients experiencing GI bleeding within the first 6 months after centrifugal and axial left ventricular assist device (LVAD) implantation, respectively (1). Furthermore, in the first 3 months after TAH implantation, hepatic dysfunction occurred at a rate of 5.2 per 100 patient-months (2). In our own large-volume TAH implantation center, we have also found an increased rate of cholecystitis requiring cholecystectomy, as compared to those who have undergone left ventricular assist device therapy in the early post-operative period.

Hepatic system

A degree of congestive hepatopathy, nodular regenerative hyperplasia or liver fibrosis is commonly seen in those with chronic right ventricular dysfunction, and at times, hepatic injury may be severe enough to lead to irreversible cirrhosis. In cardiogenic shock related to biventricular failure, there is additional hepatic injury related to ischemic under-perfusion. It is well established that the majority of TAH implants occur in INTERMACS profile 1 and 2 patients, and it is essential to assess whether there is underlying

irreversible hepatic injury prior to durable TAH therapy. This involves laboratory and imaging analysis, and at times, requires liver biopsy. The restoration of cardiac output with robust pulsatile flow from the total artificial heart seems to mitigate early hemodynamic perturbations on the hepatic system by supporting perfusion and alleviating congestion. The adverse events related to the GI/hepatobiliary systems also lessen over time as patients are further removed from their pre-implant physiologic state.

The outcome and extent of liver injury after TAH is often related to the patient's pre-operative condition. In an analysis of liver failure in TAH therapy, patients with normal liver function tests or findings of acute liver failure fared better after TAH when compared to those with significant congestive hepatopathy (3). Therefore, it is essential to optimize hepatic function through volume and perfusion management as much as possible prior to implantation.

Biliary system

Hepatic congestion can lead to cholestasis and an elevation in total bilirubin. Pre- and post-operative elevations in bilirubin levels can make it difficult to diagnose cholecystitis after TAH implantation. Most patients after TAH will have some degree of elevation in their bilirubin. At our center, we identified a larger percentage of TAH patients affected by acute cholecystitis requiring surgery, as compared to those required for LVAD patients (18% for TAH *vs.* 10% for LVAD). Notably, episodes of acute cholecystitis also occurred earlier post-TAH implantation when compared to LVAD therapy. In our experience, hepatobiliary iminodiacetic acid (HIDA) imaging had low sensitivity and specificity for acute or gangrenous cholecystitis by

pathology. One must maintain a high level of suspicion for cholecystitis after TAH, as traditional markers may be of limited diagnostic utility after device implantation. Though cholecystectomy can be safely performed in patients with TAH therapy, it is crucial to balance the operative risks with the likelihood of expected clinical benefits.

Gastrointestinal (GI) system

Bleeding occurs frequently in the early post-operative period after TAH implantation, and is commonly localized to the GI tract. Early GI bleeding is often related to the anti-platelet and anti-coagulant effects necessary for device function, balanced with the perturbations in the coagulation system in the post-operative state. There is also likely a propensity for bleeding in patients with underlying hepatic dysfunction and congestion. Thromboelastography (TEG) may be a helpful tool to help maintain “normo-coagulability” in the early vulnerable period after TAH implantation (4).

One of the important hemodynamic points of differentiation between the TAH when compared to modern LVAD therapy is pulsatility. There have been many studies evaluating the effects of pulsatility on end-organ function, and it has been theorized that the absence of pulsatility is associated with a greater incidence of ischemic and hemorrhagic complications after durable LVAD therapy (5). We therefore must look for alternative etiologies of significant GI bleeding after implantation of a pulsatile TAH system. It has been established that acquired Von Willebrand factor (vWF) syndrome is present before and after mechanical circulatory support implantation, with a post-implant increase in vWF concentrations being an independent risk factor for GI bleeding and mortality (6). This is seen in both LVAD and TAH therapies, and may be partially implicated in the rates of GI bleeding seen after TAH. Early GI bleeding after TAH is less likely to be related to arteriovenous malformations, and is more likely reflective of ischemic changes in the GI tract in the setting of anti-coagulation and critical illness, however there is currently a scarcity of data regarding this.

Future directions

There are currently multiple new artificial heart devices being designed, with a focus on improved biocompatibility, hemocompatibility, and durability. The Carmat artificial heart system (SA, Velizy Villacoublay Cedex, France) shows

promising results with early hemocompatibility and no evidence of acquired vWF in animal models (7). This may decrease the incidence of early GI bleeding episodes after implantation.

Other prospective total artificial heart therapies include the Oregon Heart (Roseville, CA, USA) and BiVACOR (Houston, TX, USA) systems, among others, which incorporate continuous-flow rotary pumps. These improvements in physiologic and hemodynamic stabilization are hoped to more closely replicate the dynamic nature of native cardiac function, and may limit post-operative adverse effects on the hepatobiliary and GI systems.

Conclusion

Appropriate pre-MCS liver assessment is a critical factor for successful outcomes after TAH implantation (8). The model for end-stage liver disease (MELD) score may be helpful in estimating pre-implant risk for hepatic injury or failure, but is difficult to apply universally to those in critical cardiogenic shock. Use of trans-jugular liver biopsy is feasible in experienced centers, both before and after TAH implantation, and may be a helpful tool to aid in risk stratification (9).

Hepatic and gastrointestinal injury commonly occur early post-TAH implantation, and this likely reflects the patient's pre-operative severity of illness rather than a direct hemodynamic effect, though this also contributes, especially in situations of post-operative vasoplegia. These findings highlight the importance of early identification of patients who may benefit from TAH therapy, with implantation as soon as possible with maximized hemodynamic optimization in order to mitigate the effects of critical illness and cardiogenic shock on the hepatobiliary and GI systems.

Acknowledgments

None.

Footnote

Conflicts of Interest: The author has no conflicts of interest to declare.

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