Creation of an atrial septal defect in beating hearts using high-intensity focused ultrasound (HIFU): Is it useful for minimally invasive fetal cardiac interventions?

Masayuki Fujisaki, Kanako Harada, Shin Enosawa, Kazuaki Sasaki, Takashi Azuma, Shinichi Takamoto, Takeyoshi Dohi, Toshio Chiba

The National Center for Child Health and Development, Tokyo, JAPAN

**Background:** The fetal cardiac interventions have been mainly aiming to prevent development of hypoplastic right or left heart syndrome (HRHS/HLHS) due to cardiac valve diseases, minimizing myocardial injuries in the fetus and to rescue the HLHS with restrictive atrial septal defect. To achieve these goals, sonographic fetal cardiomation has been employed in recent years. However, this procedure is still invasive and technically demanding. Then, we need further technical developments to treat midgestational fetal hearts less-invasively. These attempts should be oriented toward a new navigation system for accurate approach and a new surgical device for precise correction of the intracardiac tiny/fragile tissues in beating hearts. The integration of these technical innovations are sure to enable us to achieve far advanced interventions which would be essential to secure maternal safety and to prevent fetal diverse complications. High-intensity focused ultrasound (HIFU) which has been investigated originally as a tool for treatment of prostatic cancer is an acoustic technique that utilizes the ultrasound power to destroy its target tissues. If combined with a computer-programming system, HIFU might be useful to ablate fetal intracardiac tissues with pinpoint accuracy because it is unlikely to injure the target 1 s overlying or underlying tissues. The purpose of this pilot study is to develop an integrated HIFU system for correction of fetal cardiac defects.

**Method:** Adult rabbits were anesthetized and underwent thoracotomy. The exposed beating heart was covered with a film sheet. Then, the heart was placed at the bottom of a tank containing degassed water. Characteristically, our system consisted of two components: one is for the HIFU energy delivery and the other is a computer-aided programming system, both of which were functionally integrated. In this system, a 10-MHz unfocused monitoring 2-D transducer (Philips Inc.) was mounted concentric with a 4.4-MHz focused therapy transducer (focal length=26.0-mm, focal zone =0.6-4.0-mm; Hitachi Inc.) which was further mounted on a positioning system to precisely locate tissue perforations within the heart. The target tissue (atrial septum) was placed around the therapy transducer focus. Based on a specifically designed computer program, HIFU delivery was set up to be activated when the moving target (atrial septum) would encounter the focal zone and was planned so that a given set of HIFU energy (4 to 9kW/cm2) would be intermittently delivered to the target for a total of 15 seconds.

**Results:** In the rabbit beating heart, the atrial septum was successfully perforated using our integrated HIFU system. After the experiment, gross inspection of the excised heart showed that the size of each defect was 1mm to 2mm in diameter. No striking damages to the overlying and/or the underlying cardiac tissues were found. In one case the atrioventricular node was seemingly affected which was manifested by development of complete AV block during the procedure.

**Conclusion:** We demonstrated that HIFU could create a atrial septal defect in beating hearts without damaging its overlying and/or underlying tissues. This suggests that HIFU might be potentially feasible for quick and safe fetal cardiac interventionens. In addition, this system might be useful for emergency neonatal cardiac interventions.