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Impact of Subxiphoid Video Pericardioscopy with a Rigid Shaft on Cardiac Hemodynamics in a Porcine Model

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SUMMARY

Objective—Single-port subxiphoid videopericardioscopy with a rigid shaft is useful for left atrial exclusion, left ventricular pacing lead implantation, and epicardial mapping, but it may interfere with the cardiac rhythm and adversely alter hemodynamics. We examined the impact of this technique on hemodynamic indices in a porcine model.

Methods—The videopericardioscopy device was introduced into the pericardial space of 5 pigs (35–45 kg) via a subxiphoid approach and navigated to 6 anatomical targets (right atrial appendage, superior vena cava, ascending aorta, left atrial appendage (anterior and posterior approaches), transverse sinus, and atrioventricular groove). After successful target acquisition, the device was withdrawn through the subxiphoid port. When the hemodynamics stabilized, the device was navigated to another target. The heart rate, arterial blood pressure, central venous pressure, pulmonary arterial pressure, and mixed venous oxygen saturation were measured at every pre-target (subxiphoid incision) and target point. After the navigation trials, the animals were sacrificed and the mediastinum space was examined for procedure-related injuries.

Results—The device afforded a good view, and the navigation trials were successfully performed on the beating heart. Four animals tolerated the procedures, while 1 died of device-induced ventricular fibrillation after the trials. Hemodynamics were severely compromised at all anatomical targets except the left atrial appendage (anterior approach).

Conclusions—Subxiphoid videopericardioscopy significantly interferes with the cardiac rhythm, causing life-threatening arrhythmia and hemodynamic compromise, when the target is located deep and far from the pericardiotomy. A flexible or highly articulated device would enable intrapericardial navigation without hemodynamic compromise.

Keywords

Minimally invasive; Cardiac surgery; Subxiphoid approach

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INTRODUCTION

Recent advances in surgical techniques and equipment have reduced the invasiveness of traditional surgical techniques. With newly developed techniques for minimally invasive cardiac surgery (MICS), the heart can be accessed through small incisions, without the need for inducing cardiac arrest, performing full sternotomy, or using a heart-lung machine. We previously developed subxiphoid videopericardioscopy (SVP) with a rigid shaft as a novel MICS approach. This approach provides subxiphoid access and enables therapeutic delivery, and we have reported its effectiveness for left atrial appendage exclusion, pacing lead implantation, and epicardial mapping [1,2,3]. However, the rigid shaft of the SVP device may interfere with the cardiac rhythm and thus adversely influence hemodynamics. The objective of this study was to examine the influence of SVP on hemodynamics in a porcine model.

METHODS

Subjects

The study involved 5 large healthy Yorkshire swine (median weight, 45 kg). All the animals received humane care in compliance with the Guide for the Care and Use of Laboratory Animals, published by the National Institutes of Health in 1996. The study protocol was approved by the Institutional Animal Care and Use Committee of the University of Pittsburgh.

Surgical preparation

All animals were anesthetized with intramuscular injections of 20 mg/kg ketamine and 2 mg/kg xylazine, and 1–2% isoflurane was delivered using a face mask. The animal was placed in the supine position and endotracheally intubated. The state of anesthesia was maintained using 1–5% isoflurane. Electrocardiography was performed to monitor the heart rate (HR). The right carotid artery and jugular vein were exposed through an incision on the right side of the neck, and the right carotid artery was cannulated with a 6-Fr catheter to monitor the arterial blood pressure (BP). The jugular vein was cannulated with a 7-Fr Swan-Ganz catheter to monitor the central venous pressure (CVP), pulmonary artery pressure (PAP), and mixed venous oxygen saturation (SvO₂).

Subxiphoid videopericardioscopy technique

A 15-mm subxiphoid incision was made, and the underlying tissue was minimally dissected to the pericardial level. Further, a small pericardiotomy (5 mm) was created under direct visualization. An SVP device (FLEXView System; MAQUET Cardiovascular, San Jose, CA) consisting of a 7-mm extended length endoscope with 2 proximal entry service ports (Figure 1) was then inserted into the pericardial cavity via a subxiphoid approach (Figure 2).

Navigation trials

Guided by the endoscopic view displayed on a monitor, the surgeon manipulated the SVP device and thus performed trials of navigation to 6 anatomical targets (right atrial appendage, superior vena cava, ascending aorta, left atrial appendage, transverse sinus, and atrioventricular groove). The left atrial appendage can be targeted via the anterior approach or posterior approach: in the anterior approach, the SVP device runs along the surface of the anterior left ventricle from the subxiphoid incision towards the left atrial appendage, and in the posterior approach, the SVP device runs over the surface of the posterolateral left ventricle from the subxiphoid incision towards the left atrial appendage. When the device reached a target, it was drawn out to the subxiphoid incision. After the hemodynamics stabilized, the SVP was navigated toward another target. Hemodynamic parameters, namely, the HR, BP, CVP, PAP, and SvO₂, were measured at each pre-target (subxiphoid incision) and target point.

Analytical methods

The quantitative results were expressed as the mean $\pm$ standard deviation and analyzed using a software package for statistical analysis (Stata/IC software, version 10.0; Stata Corp., College Station, TX). Wilcoxon's signed-rank test was used to determine the significance of the difference. P values of less than 0.05 were considered statistically significant.

RESULTS

The navigation trials were successfully performed on the beating heart. The built-in camera of the SVP device provided a sufficiently good view for navigation. There were no instances of cardiac injury or hemorrhage in any of the trials. Four animals tolerated the procedures until the time of euthanasia, but 1 died of ventricular fibrillation. When the subject suffered from refractory ventricular fibrillation, it indicated that the target location at the AV groove was being approached. All the hemodynamic parameters, especially the BP and SvO₂, were adversely affected by the SVP device, except during navigation to the left atrial appendage (anterior approach; Table 1).

DISCUSSION

MICS is an evolving strategy aimed at delivering the desired form of cardiovascular therapy with minimal homeostatic changes. Computer-assisted surgery and robotic cardiac surgery have gained popularity as strategies for MICS. These strategies have evolved from videoscopic procedures and have been used for complex mitral valve repair and replacement, surgical treatment of atrial fibrillation (AF), left-ventricular (LV) mapping, insertion of epicardial LV pacing leads, internal mammary artery (IMA) harvesting, and coronary bypass grafting [4]. However, they require multiple ports and lung deflation [5,6]. We developed a novel MICS approach for subxiphoid access and therapeutic delivery. This approach is appealing because it provides access to the pericardial space through a single port, without the need for full sternotomy, general endotracheal anesthesia, or lung deflation. However, a major problem associated with the present configuration of the SVP device is its rigidity, which causes cardiac compression. Most anatomical targets for videopericardioscopy are located in remote areas of the pericardium, away from the entry point below the xiphoid process. The extent of hemodynamic compromise caused by the SVP device has not been discussed before. In this study, we examined the influence of this device on hemodynamics in a porcine model.

We performed trials of navigation to 6 anatomical targets because we thought that these anatomic structures are potentially important clinical therapeutic targets, and found that the SVP device triggered life-threatening arrhythmia and caused severe hemodynamic compromise, except during navigation to the left atrial appendage (anterior approach). The device triggers these conditions because its rigid shaft interferes with the cardiac rhythm when the target is located deep and far from the pericardiotomy in a subxiphoid approach. We believe the most likely explanation for the malignant arrhythmia episode at the AV groove was distortion of the left ventricular outflow tract and kinking of the left anterior descending coronary artery.

If this physical limitation of the SVP device, i.e., its rigidity, could be overcome, many cardiovascular therapies involving the epicardium (epicardial ventricular and atrial ablation, left atrial appendectomy, pulmonary vein electrical isolation, myocardial revascularization, cell transplantation, injection of growth factors, and gene therapy) could be performed via the subxiphoid approach.

The transdiaphragmatic approach allows the use of different and more favorable vectors in the pericardium; alternatively, a camera with a soft, plastic insulating cover may improve

intrapericardial navigation. However, our study was limited to extraperitoneal subxiphoid videopericardioscopy and the physical constraint (rigidity) of the SVP device. We recently developed a novel, highly articulated, robotic probe (ARM) [7,8] that provides unlimited but controllable flexibility for navigation through the anatomical complexity of the mediastinum. The ARM consists of serially connected, rigid cylindrical links with flexible working ports through which catheter-based tools for therapy and imaging can be advanced. It is controlled by a computer-driven user interface, which is operated outside the surgical field. The ARM offers promise for the development of many new therapies involving the epicardium.

Although this study has yielded valuable findings, several limitations need to be overcome. First, because the sample size is small further studies are required to confirm the disadvantages of SVP. Second, the porcine model differs from humans with respect to the position of the heart in the mediastinum; moreover, the body weight is lesser than that of humans, and it is difficult to compare the dimensions with those of humans. Third, pigs are notoriously susceptible to arrhythmias, but this does not necessarily imply that a similar problem would occur in humans. Fourth, because the visualization did not incorporate a therapy, incorporation of a therapy (e.g., epicardial lead placement) would have prolonged the visualization time and further compromised the hemodynamics.

In conclusion, we examined the hemodynamic impact of SVP performed via a subxiphoid approach. Our results indicated that the SVP device triggered life-threatening arrhythmia and caused severe hemodynamic compromise when the target was located deep and far from the pericardiotomy. Nevertheless, we believe that therapeutic delivery via a subxiphoid approach is useful for MICS strategies involving the epicardium. Our next immediate research goal is to develop a novel, highly articulated, robotic probe that can be navigated through the anatomical complexity of the mediastinum.

Clinical Perspective

This experimental study examines the effect of single port subxiphoid videopericardioscopy with a rigid shaft device on hemodynamic indices in a porcine preparation. This is a timely article in that videopericardioscopy is a potential useful technique for a number of less invasive epicardial interventions. It is currently being used in some centers for surgical ablation of atrial fibrillation. The authors found that the device afforded good anatomical visualization. However, hemodynamics were significantly compromised in all anatomical _____ except the left atrial appendage. The authors recommended the development of a flexible, articulated device that may enable intrapericardial navigation without hemodynamic compromise. The readers should be cautioned from extrapolating these findings directly to a clinical situation. First of all, this device has been used clinically without particular problems with maintaining stable hemodynamics. The reason may be the difference in geometry between the human and porcine chests. Pigs are also notoriously prone to arrhythmias and this may not extrapolate to the human situation. Finally, some clinicians have been using a transdiaphragmatic approach in their clinical cases while these authors used an extraperitoneal subxiphoid entry which may have also affected their results. Despite these limitations, the authors are to be congratulated for examining the potentially enabling minimally invasive technology in an experimental model.

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Figure 1.
The SVP device (FLEXView System; MAQUET Cardiovascular, San Jose, CA) consisting of a 7-mm extended length endoscope with 2 proximal entry service ports.

Figure 2.
A 15-mm subxiphoid incision and a 5-mm pericardiotomy were made under direct visualization.

Table 1

Percent Change in Hemodynamic Parameters From Baseline (Pretarget) During the Navigation Trials

	Intrapericardial Targets						
	RAA	SVC	AO	LAA-ANT	LAA-POST	TRANS V Sinus	AV Groove
Systolic ABP	[minus]10.1 [plusmn] 11.3	[minus] 31.6 [plusmn] 8.4*	[minus] 28.7 [plusmn] 17.6*	[minus] 5.5 [plusmn] 16.0	[minus] 34.9 [plusmn] 16.0*	[minus] 48.0 [plusmn] 17.2*	[minus] 24.9 [plusmn] 6.3*
Diastolic ABP	[minus]12.4 [plusmn] 18.4	[minus] 39.3 [plusmn] 11.1*	[minus] 31.1 [plusmn] 24.6*	[minus] 13.5 [plusmn] 29.4	[minus] 45.6 [plusmn] 21.5*	[minus] 49.5 [plusmn] 19.3*	[minus] 29.1 [plusmn] 5.5*
Mean ABP	[minus]7.3 [plusmn] 15.5	[minus] 43.9 [plusmn] 17.9*	[minus] 34.1 [plusmn] 21.7*	[minus] 12.1 [plusmn] 20.3	[minus] 41.8 [plusmn] 20.6*	[minus] 47.2 [plusmn] 19.5*	[minus] 27.0 [plusmn] 7.7*
Systolic PAP	1.2 [plusmn] 5.2	[minus] 7.5 [plusmn] 12.9	[minus] 12.7 [plusmn] 8.9	[minus] 4.4 [plusmn] 8.6	[minus] 9.5 [plusmn] 14.9	[minus] 12.7 [plusmn] 29.8	[minus] 1.7 [plusmn] 8.7
Diastolic PAP	10.7 [plusmn] 18.4	7.6 [plusmn] 20.9	[minus] 14.8 [plusmn] 12.6	[minus] 15.9 [plusmn] 14.0	[minus] 5.1 [plusmn] 10.8	[minus] 9.2 [plusmn] 6.6	2.9 [plusmn] 16.1
Mean PAP	1.9 [plusmn] 6.6	1.8 [plusmn] 16.4	[minus] 12.2 [plusmn] 16.4	[minus] 4.0 [plusmn] 6.7	[minus] 13.3 [plusmn] 7.1*	[minus] 12.1 [plusmn] 21.1	[minus] 3.0 [plusmn] 8.9
CVP	14.1 [plusmn] 4.6	8.1 [plusmn] 16.4	17.8 [plusmn] 27.1	1.6 [plusmn] 16.3	14.3 [plusmn] 26.4	10.4 [plusmn] 12.3	17.9 [plusmn] 16.2
SVO2	[minus]7.2 [plusmn] 3.0	[minus] 27.9 [plusmn] 10.9*	[minus] 46.3 [plusmn] 19.8*	[minus] 7.3 [plusmn] 8.3	[minus] 52.3 [plusmn] 10.8*	[minus] 45.4 [plusmn] 5.5*	[minus] 48.6 [plusmn] 6.1*

The percentages were analyzed by Wilcoxon's signed-rank test

* P < 0.05 vs. baseline.

ABP indicates arterial blood pressure; PAP, pulmonary arterial pressure; SVC, superior vena cava; RAA, right atrial appendage; AO, ascending aorta; LAA-ANT, left atrial appendage (anterior approach); LAA-POST, left atrial appendage (posterior approach); TRANSV sinus, transverse sinus.