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Laboratory Investigation

Pericardial Access Through the Right Atrium in a Porcine Model

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As procedures such as epicardial ventricular ablation and left atrial appendage occlusion become more commonplace, the need grows for safer techniques to access the physiologic pericardial space. Because this space contains minimal fluid for lubrication, prevailing methods of pericardial access pose considerable periprocedural risk to cardiac structures. Therefore, we devised a novel method of pericardial access in which carbon dioxide (CO_2) is insufflated through a right atrial puncture under fluoroscopic guidance, enabling clear visualization of the cardiac silhouette separating from the chest wall. We performed the procedure in 8 Landrace pigs, after which transthoracic percutaneous pericardial access was obtained by conventional means. All of the animals remained hemodynamically stable during the procedure, and none showed evidence of epicardial or coronary injury. The protective layer of CO_2 in the pericardial space anterior to the heart facilitated percutaneous access in our porcine model, and the absence of complications supports the potential safety of this method. ***(Tex Heart Inst J 2021;48(1):e207244)***

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Securing percutaneous access to the pericardial space is a necessary step in performing several evolving catheter-based epicardial procedures, including left atrial appendage occlusion[1] and mapping and ablation of epicardial ventricular arrhythmias.[2,3] Currently, transthoracic pericardial access techniques are best suited for evacuating a fluid-filled pericardial space. However, newer procedures necessitate accessing the physiologic pericardial space, which contains only 20 mL of fluid for lubrication.[4] In these "dry-tap" cases, the transthoracic approach requires that a long needle be directed through the body wall and carefully inserted, under fluoroscopic or ultrasonographic guidance, between the pericardium and the surface of the beating heart,[5] which poses several risks to the patient.[6] Injuries (for example, ventricular rupture or coronary vessel laceration[1,6]) can occur and often necessitate emergency surgical repair. A safe and reproducible technique for obtaining pericardial access that decreases the need for precision would be of value as dry-tap access becomes more commonplace.

We studied the potential merit of insufflating the pericardial space with carbon dioxide (CO_2) delivered through the right atrial wall with a needle-tipped intravenous catheter, to enable easier percutaneous access through the body wall.

Materials and Methods

Eight Landrace pigs (weight range, 69–81 kg) were anesthetized, intubated, and secured in the supine position. Femoral venous access was obtained with a 6F sheath, and heparin (2,000 IU) was administered systemically. A 6F multipurpose catheter (FlexCath; Cook Medical) was then inserted through the sheath and advanced over a 0.35-in guidewire; under fluoroscopic guidance, the catheter was advanced through the inferior vena cava and into the right atrium, and finally into the superior vena cava. The guidewire was removed, after which the tip of the multipurpose catheter was pulled back until its tip fell into the right atrial appendage. The catheter's position was confirmed by fluoroscopy with a radiopaque contrast agent (Omnipaque; GE Healthcare) (Fig. 1). A 200-cm-long, 6F catheter with a reversibly extendable 25G needle tip (Interject Catheter; Boston Scientific) was inserted through the lumen of the 6F multipurpose catheter until the tip was adjacent to the right atrial appendage wall. When the plunger at the back end of the Interject Catheter is depressed, the 25G needle extends 3 mm beyond the catheter tip.

During fluoroscopy, the C-arm was adjusted to obtain a cross-table lateral image of the animal's mediastinum. A syringe, connected by tubing and a 3-way stopcock to a CO_2 tank and to the Interject Catheter, was filled with sterile CO_2. The needle at the tip of the Interject Catheter was gently pressed against the right atrial wall and extended through it into the pericardial space. Two 60-mL injections (total, 120 mL) of the sterile CO_2 were then delivered from the syringe into the pericardial space through the Interject Catheter without entraining room air.

Percutaneous access to the pericardial space was then obtained with a long needle according to standard practice.[5] Radiopaque contrast agent was injected to confirm access. Next, the remaining CO_2 in the pericardial space was evacuated through the percutaneous needle, to enable tissue layers to reseal. Finally, each pig was humanely killed, and necropsy was performed immediately to assess cardiac structures.

This study conformed to the Guide for the Care and Use of Laboratory Animals. The protocol was approved by the Institutional Animal Care and Use Committee of the Texas Heart Institute at Baylor St. Luke's Medical Center.

Results

Pericardial access was successfully obtained by needle puncture in all 8 pigs. After 120 mL of sterile CO_2 had been delivered into the pericardial space, the visceral and parietal pericardial layers were successfully separated. This was confirmed fluoroscopically (Fig. 2). No CO_2 leaked into the right atrium.

When the pigs were placed in a supine position, the insufflated CO_2 accumulated toward the chest wall in the pericardial space. When seen laterally on fluoroscopy, the heart rested posteriorly. Furthermore, because cardiac tissue and CO_2 have different radiopaque densities, the pericardial space was easily discernible on a cross-table lateral image (Fig. 3).

In all 8 pigs, radiographs confirmed that the visceral and parietal pericardial layers sealed. All animals remained hemodynamically stable and showed no evidence of cardiac tamponade. Necropsy studies revealed no damage to the ventricles or coronary arteries, healing of the puncture in the right atrial wall, and no evidence of blood leaks.

Discussion

As epicardial ventricular arrhythmia ablation and left atrial appendage occlusion procedures become more commonplace, safer methods of pericardial access are needed to access a physiologically normal pericardial space in dry-tap fashion. Our method proved feasible for standard transthoracic pericardial access.

The conventional transthoracic approach is appropriate for patients in whom a substantial amount of fluid

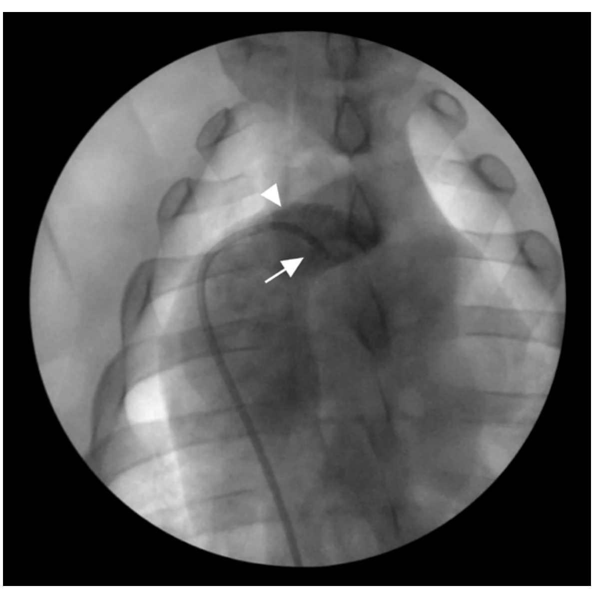

Fig. 1 *Fluoroscopic image (anterior view) with radiopaque contrast shows the position of the catheter (arrow) in the right atrium (arrowhead).*

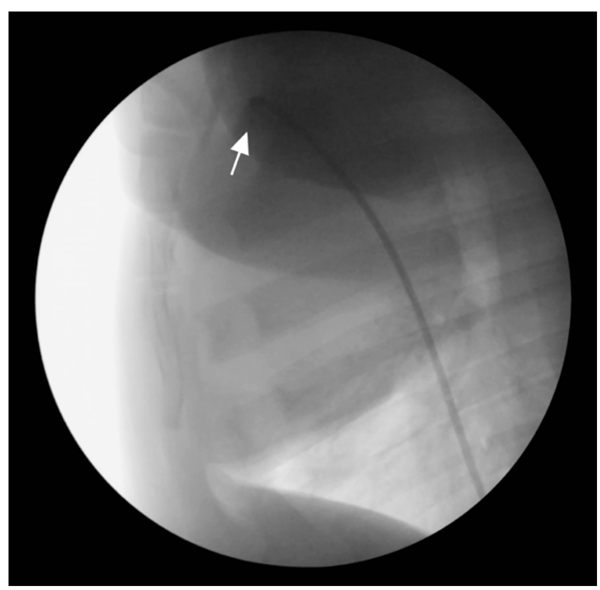

Fig. 2 *Fluoroscopic image (lateral view) shows pericardial access obtained with the needle-tipped catheter (arrow) through the right atrial wall.*

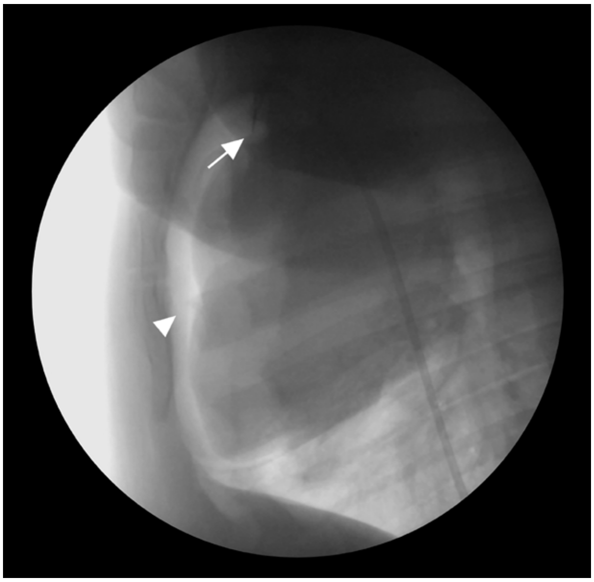

Fig. 3 *Fluoroscopic image (lateral view) shows pericardial accumulation of CO_2 (arrowhead) after insufflation through the needle-tipped catheter (arrow). The cardiac silhouette is easily discernible because of the differing densities and radiopaque properties of CO_2 and myocardial tissue.*

has collected in the pericardial space. However, in a dry tap of the normal pericardial space, the transthoracic approach poses substantial risk to cardiac structures. Right ventricular perforation is the most common complication,[3,6] and major complications occur in approximately 9% of procedures.[3] Furthermore, the presence of a needle or guidewire in an evacuated pericardial space, in addition to cardiac motion, poses a risk of another feared complication, coronary artery laceration.[7,8] Pericardial CO_2 insufflation may mitigate these risks to the patient.

Several other methods to alleviate the risk of dry-tap access have been described. In a multicenter observational study, Gunda and colleagues[7] found that using a micropuncture needle resulted in fewer complications than when using a large-bore needle (for example, the Tuohy or Pajunk needle). In another multicenter study,[9] investigators successfully used a device that houses a fiberoptic pressure sensor within the access needle (EpiAccess; EpiEP, Inc.) to facilitate epicardial access. The sensor provides visual feedback on pressure differences as the needle advances through different tissue layers. Burkland and associates[10] have introduced a similar device that relies on impedance feedback to determine the location of the needle.

Despite progress, no innovation has eliminated the need to introduce a needle into the pericardial space or reduced the risk of complications. Our technique, when used as a supplement to various transthoracic pericardial techniques, may help to reduce these risks.

Puncturing the right atrial wall with a needle-tipped intravenous catheter to insufflate CO_2 enabled the visceral and parietal layers of the pericardium to be safely separated without introducing a catheter wire into the pericardial space. During the procedure, blood from the right atrium did not escape into the pericardial space, and when the wire was removed, the right atrial appendage did not bleed.

Carbon dioxide has 2 properties that make it particularly useful for insufflation: relative density and radiopaque discernibility. Because CO_2 is lighter than cardiac tissue, it rises toward the chest wall when the subject is supine and causes the heart to sink. The differing radiopaque appearances of gas and myocardial tissue enable clearer visualization. Thus, the space created by the CO_2 simplifies transthoracic access. Conversely, using a crystalloid fluid to fill the pericardial space would not enable a clear view because the heart would appear as dense as the fluid during fluoroscopy. Furthermore, the positioning of the heart would be less stable because crystalloid fluids and cardiac tissue and blood have similar densities.

In this porcine study, pericardial insufflation with CO_2 was well tolerated. We observed no evidence of cardiac tamponade in any pig. Theoretically, because CO_2 is highly soluble, any CO_2 that leaked inside the right atrium would dissolve and be exhaled.[11]

Although this study demonstrated the feasibility of our pericardial access technique, there are limitations to consider. First, the sample size (8 pigs) was small. Larger additional studies in animals and eventually in humans will be needed to reveal any complications associated with the technique. The main potential complication is myocardial puncture leading to effusion or tamponade, an adverse event commonly associated with the standard pericardial access procedure. Second, injecting CO_2 into the right atrium could theoretically cause air embolism, but this risk is probably minimal, given that CO_2 is soluble and converts to bicarbonate in plasma.[11] Third, the standard limitations of studies in animal models apply, in particular the uncertain applicability of the technique to human anatomy and physiology in both subxiphoid pericardial access and right atrial location under fluoroscopic guidance.

Conclusions

This porcine study demonstrates the feasibility of insufflating CO_2 into the pericardial space to facilitate safer percutaneous pericardial access. Because CO_2 is easily discernible radiographically and preferentially gathers anterior to the heart, pericardial CO_2 would provide a protective layer that makes percutaneous access safer.

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