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The Pressure Waveform of Coronary Sinus in Human Hearts

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Key Words
cardioplegic solutions;
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coronary vessels

Background. The pressure waveform of coronary sinus in human hearts has never been well described. Retrograde cardioplegia perfusion has become a popular method of myocardial protection in recent years, and identification of the pressure waveform of the coronary sinus might help intubate the coronary sinus in retrograde cardioplegia perfusion by differentiating it from that of the right atrium. The purpose of this study is to identify the pressure waveform of the coronary sinus.
Methods. We inserted a catheter into the coronary sinus under direct vision via a right atriotomy after completion of open heart operation in eight patients. The pressure waveforms of coronary sinus and central venous line, as well as the electrocardiogram (EKG), were recorded simultaneously after the patient was stable and weaned from the cardiopulmonary bypass. The recorded pressure waveforms of coronary sinus and central venous line were compared.
Results. The pressure waveform of coronary sinus was found to have three peaks, more prominent than those of the central venous line waveform.
Conclusions. The pressure waveform of coronary sinus could be distinguished from that of the central venous line. The difference might help coronary sinus cannulation for retrograde cardioplegia perfusion.
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Adequate myocardial protection is the prerequisite of a safe and successful open heart operation. Retrograde cardioplegia perfusion is found better in this sense than antegrade cardioplegia in patients with diffuse atherosclerotic stenotic coronary diseases.[1-3] It is an attractive alternative of cardioplegia delivery for patients receiving aortic valve replacement.[4,5] It also offers several advantages over antegrade delivery in "redo" cardiac operations.[6,7] Retrograde cardioplegia perfusion requires more demanding techniques, and carries potential hazard of coronary sinus injury and right ventricle dysfunction.[8,9] However, improvements have been made for retrograde cardioplegia perfusion to promote its safety, efficacy and feasibility, such as sophistication in the design of catheter[10,11] and transesophageal echocardiographic guidance to direct coronary sinus cannulation.[12]

The pressure waveform of coronary sinus in human has not been reported, though many interventions or operations involving the coronary sinus have been done for treatment of various heart diseases.[13-15] The purpose of this study is to identify such pressure waveform in human, and to compare it with that of the central venous line, hoping it may help coronary sinus intubation for retrograde cardioplegia perfusion so

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Table 1. Clinical characteristics of patients

Patient	Age (year)	Sex	Diagnosis	Operations
1	67	Male	CAD	CABG
2	67	Male	CAD	CABG
3	81	Male	CAD	CABG
4	4	Female	ASD	ASD Repair
5	14	Female	ASD	ASD Repair
6	4	Male	VSD	VSD Repair
7	18	Female	VSD	VSD Repair
8	63	Male	AS	AVR

AS = aortic stenosis; ASD = atrial septal defect; AVR = aortic valve replacement; CABG = coronary artery bypass grafting; CAD = coronary artery disease; VSD = ventricular septal defect.

that safety and feasibility can be promoted.

Methods

This study was approved by the Human Research Committee of Taipei Veterans General Hospital and was conducted in accordance with local ethical standards. This study involved eight patients who underwent open heart surgery in Veterans General Hospital-Taipei between 1997 and 1998. Five of the patients were male and three were female, aged from 4 to 81 years (Table 1). Three patients (1, 2, and 3) received coronary artery bypass grafting (CABG) operation for stenotic coronary artery disease. Retrograde coronary sinus cardioplegia perfusion under direct vision was used due to high degree (90%) stenosis of the left main coronary artery (patient 1) or the left anterior descending coronary artery (patients 2 and 3). Two patients (4 and 5) underwent repair of atrial septum defect via right atriotomy. Two patients (6 and 7) received repair of ventricular septum defect through right atriotomy approach. Patient 8 received aortic valve replacement for critical aortic stenosis and severe aortic regurgitation. Bi-caval cannulation and right atriotomy were performed in all eight patients. All patients received either a central venous catheter (ARROW, International, Inc., Reading, PA, USA) or a Swan-Ganz balloon catheter (ARROW, International, Inc., Reading, PA, USA) for central venous pressure monitoring during the operation.

After completion of the operation and before closure of the right atriotomy, a purse-string suture was placed in the right atrium. A 16 GA catheter (ARROW, International, Inc., Reading, PA, USA) used as a coronary sinus catheter passed through the purse-string suture and directed into the coronary sinus under direct vision (Fig. 1). The distal end of the coronary sinus catheter was connected to the transducer of HP Component Monitoring System (Hewlett-Packard Company, Andover, MA, USA). After patients were stable and weaned from the cardiopulmonary bypass, the pressure waveforms of coronary sinus and central venous line, as well as the electrocardiogram (EKG), were recorded simultaneously. The differences of both waveforms were compared.

Results

No mortality or morbidity occurred in this study. Three peaks in the pressure waveform of coronary sinus were observed in these eight patients (Fig. 2 and Fig. 3). The first peak appeared after the "p" wave of EKG, signaling atrial contraction. The second peak coincided with T-wave in the EKG, representing ventricular contraction and atrial filling. The third peak was found to interpose between these two peaks, immediately after the QRS complex in the EKG. There were, however, only two peaks in the pressure waveform of the central venous line. The first peak also ap-

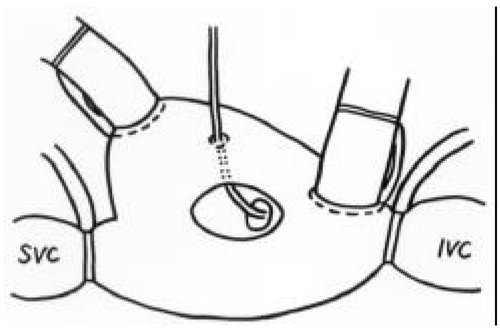

Fig. 1. The catheter was inserted into the coronary sinus under direct vision via a small stab within a purse-string suture in the right atrium after completion of the operation. (IVC = inferior vena cava, SVC = superior vena cava).

peared after the “p” wave in the EKG, and the other peak appeared after QRS complex. These two peaks were much flatter and less evident than those in the pressure waveform of the coronary sinus.

Discussion

The pressure waveform of coronary sinus in human hearts has never been described before. Gensini and his associate introduced a cardiac catheter to pass into the coronary sinus via the right jugular vein with conventional catheterization techniques in 75 dogs. The pressure waveform of coronary sinus in these dogs was found to be composed of evident “a”, “c”, and “v” waves,[16] similar to our findings in human. Faxon and his associate showed the pressure tracing of the coronary sinus in 27 patients on acute occlusion by

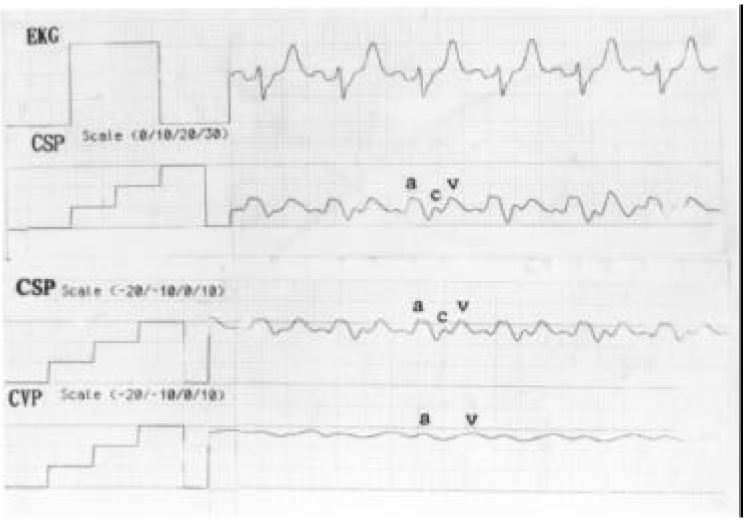

Fig. 2. The recordings of ECG, pressure waveforms of coronary sinus and central venous line of patient 1, a 67-year-old male with coronary artery disease and stenosis of the left main coronary artery. (CSP = coronary sinus pressure, CVP = central venous pressure).

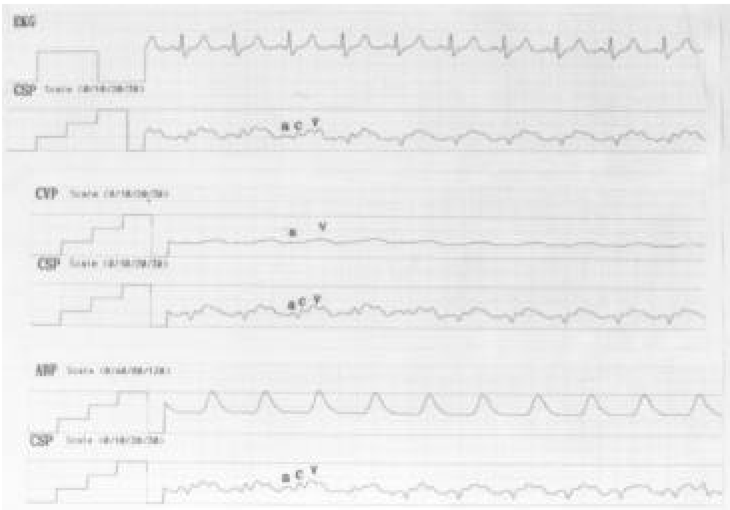

Fig. 3. The recordings of ECG, pressure waveforms of coronary sinus and central venous line of patient 7, a 18-year-old female with perimembranous type ventricular septal defect. (ABP = arterial blood pressure, CSP = coronary sinus pressure, CVP = central venous pressure).

balloon inflation of balloon-tipped catheter.[17] An initial early systolic peak and a later higher systolic peak occurred at the end of systole and were closely timed with the "v" wave in the pulmonary wedge tracing. The measured pressure of the second peak in their study was about 43 mmHg, significantly higher than our measurement. However, their pressure tracing of the coronary sinus was done in condition of coronary sinus occlusion, which could cause deviation from the normal beating heart condition.

It is not understood why "c" wave was not discernible in the pressure tracing of central venous line in our study, as it has occasionally been identified in previous reports.[18,19] Right ventricle contraction elevating the cusps of the tricuspid valve, coronary veins emptying into the right atrium, and a temporary rise in intra-thoracic pressure from ventricular ejection have been suggested to be the origin of the "c" wave of jugular vein pulse.[20] We surmised that the open chest condition may obscure the "c" wave because the pressure produced by bulging of tricuspid valve might be better accommodated by the right atrium in open chest than in closed state. On the other hand, the increased blood return in systolic phase that would be accommodated poorly by the much smaller chamber of the coronary sinus might partly explain the occurrence of the pronounced "c" wave in the coronary sinus pressure waveform.

The waveforms of pressure tracing differ in different heart chambers. In clinical practice of Swan-Ganz Catheter insertion, we make use of the difference of waveforms in the right atrium, the right ventricle and the pulmonary artery to float the pulmonary artery catheter into the correct position.[21] In the setting of coronary sinus catheterization, surgeons may observe the change of pressure tracing while advancing the coronary sinus catheter, blindly without touching the heart, through the right atrium into the coronary sinus until a coronary sinus pressure waveform was obtained.[6]

From our limited observation, we could identify the pressure waveform of coronary sinus from their prominent peaks appearing in the pressure tracing. The pressure waveform of coronary sinus could be distinguished from that of the central venous line by different shape. More observations should be done in more patients to characterize the coronary sinus pressure waveform in detail. With more experience gained, the surgeons may intubate the coronary sinus for retrograde cardioplegia delivery blindly and without touching the right atrium by identifying the pressure waveform of coronary sinus.

References

1. Buckberg GD. Recent advances in myocardial protection using antegrade/retrograde blood cardioplegia. *Eur Heart J* 1989;10 (Suppl H):43-8.
2. Diehl JT, Eichhorn EJ, Konstam MA, Payne DD, Dresdale AR, Bojar RM, et al. Efficacy of retrograde coronary sinus cardioplegia in patients undergoing myocardial revascularization: a prospective randomized trial. *Ann Thorac Surg* 1988;45:595-602.
3. Noyez L, van Son JAM, van der Werf T, Knape JT, Gimbrere J, van Asten WN, et al. Retrograde versus antegrade delivery of cardioplegic solution in myocardial revascularization. *J Thorac Cardiovasc Surg* 1993;105:854-63.
4. Menasche P, Subayi J, Piwnica A. Retrograde coronary sinus cardioplegia for aortic valve operations: a clinical report on 500 patients. *Ann Thorac Surg* 1990;49:556-64.
5. Fiore AC, Naunheim KS, McBride LR, Pennington DG, Kaiser GC, Castanis J, et al. Aortic valve replacement: aortic root versus coronary sinus perfusion with blood cardioplegic solution. *J Thorac Cardiovasc Surg* 1992;104:130-8.
6. Gundry SR, Razzouk AJ, Vigesaa RE, Wang N, Bailey LL. Optimal delivery of cardioplegic solution for "redo" operations. *J Thorac Cardiovasc Surg* 1992;103:896-901.
7. Snyder HE, Smithwick W III, Wingard JT, Agnew RC. Retrograde coronary sinus perfusion. *Ann Thorac Surg* 1988; 46:389-90.
8. Panos AL, Ali IS, Birnbaum PJ, Barrozo CAM, al-Nowaiser O, Salerno TA. Coronary sinus injuries during retrograde continuous normothermic blood cardioplegia. *Ann Thorac Surg* 1992;54:1137-8.
9. Menasche P, Piwnica A. Retrograde cardioplegia through the coronary sinus. *Ann Thorac Surg* 1987;44:214-6.
10. Gundry SR, Sequiera A, Razzouk AM, McLaughlin JS, Bailey LL. Facile retrograde cardioplegia: transatrial cannulation of the coronary sinus. *Ann Thorac Surg* 1990; 50:882-7.
11. Drinkwater DC, Laks H, Buckberg GD. A new simplified method of optimizing cardioplegic delivery without right heart isolation. *J Thorac Cardiovasc Surg* 1990;100:56-64.
12. Aldea GS, Connelly G, Fonger JD, Dobnick D, Shemin RJ. Directed atraumatic coronary sinus cannulation for retro-

grade cardioplegia administration. *Ann Thorac Surg* 1992; 54:789-90.
13. Lazar HL. Coronary sinus interventions during cardiac surgery. *Ann Thorac Surg* 1988;46:475-82.
14. Hammond GL, Davies AL, Austen WG. Retrograde coronary sinus perfusion: a method of myocardial protection in the dog during left coronary artery occlusion. *Ann Surg* 1967;166:39-47.
15. Kalmbach T, Bhayana JN. Cardioplegia delivery by combined aortic root and coronary sinus perfusion. *Ann Thorac Surg* 1989;47:316-7.
16. Gensini GG, DiGiorgi SD, Murad-Netto S. Coronary venous occluded pressure. *Arch Surg* 1963;86:72-80.
17. Faxon DP, Jacobs AK, Kellett MA, McSweeney SM, Coats WD, Ryan TJ. Coronary sinus occlusion pressure and its relation to intracardiac pressure. *Am J Cardiol* 1985;56:457-60.
18. Schwenzer KJ. Venous and pulmonary pressures. In: Lake CL, ed. *Clinical Monitoring for Anesthesia and Critical Care.* 2nd ed. Philadelphia: W.B. Saunders, 1994:132-3.
19. Sharked SW. Beyond the wedge: clinical physiology and the Swan-Ganz catheter. *Am J Med* 1987;83:111-22.
20. Rich LL, Tavel ME. The origin of the jugular c wave. *N Engl J Med* 1971;284:1309-11.
21. Swan HJ, Ganz W, Forrester J, Marcus H, Diamond G, Chonette D. Catheterization of the heart in man with use of a flow-directed balloon-tipped catheter. *N Engl J Med* 1970; 283:447-51.