Assessment of myocardial distribution of retrograde and antegrade cardioplegic solution in the same patients

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Abstract

Objective: In order to clarify intramyocardial delivery and distribution of retrograde cardioplegic solution in humans, we induced both ante- and retrograde methods in the same patients to compare their respective delivery and distribution using myocardial contrast echocardiography during surgery. Methods: 15 patients consisting of nine patients with valvular heart diseases and six patients with coronary artery diseases (including two patients with myocardial infarcted areas and two patients with areas supplied by coronary collateral situation associated with totally occluded coronary arteries without myocardial infarction). Induction of cardioplegia was initially accomplished antegradely and thereafter retrogradely. Results: In valvular heart disease, retrograde cardioplegic solution was distributed less homogeneously, and was not delivered to the midportion of the interventricular septum in two-thirds of the patients (6/9). The transmural myocardial distribution in the anterior, lateral, and posterior walls in the left ventricle were similar for both ante- and retrograde cardioplegic solution, while delivery to the endocardial halves was better than to the epicardial halves (endo-/epicardial intensity ratio in antegrade versus retrograde: 1.31 ± 0.24 versus 1.29 ± 0.26; 1.19 ± 0.05 versus 1.36 ± 0.23; 1.33 ± 0.28 versus 1.44 ± 0.35, respectively (all N S)). For delivery to the right ventricle, the existence of small cardiac vein was important. In patients with small cardiac vein (34% in our study), the delivery to the right ventricular dorsal walls was shown. In coronary heart disease, retrograde cardioplegic solution was well delivered to the areas by coronary collateral situation associated with totally occluded coronary arteries, but antegrade solution was not. Neither ante- nor retrograde solution was delivered to myocardial infarcted areas. Conclusions: These results have important implications for planning strategies for myocardial protection. We think that it is necessary to fully grasp the coronary arterial and venous anatomy of individual patients and to know how to use either ante-or retrograde cardioplegia properly. © 1997 Elsevier Science B.V.

Keywords: Myocardial delivery and distribution; Retrograde cardioplegia; Antegrade cardioplegia; Coronary anatomy

1. Introduction

The clinical application of cardioplegia through the coronary sinus (retrograde cardioplegia) is increasing and several reports attest to its efficacy [1–3]. Retrograde cardioplegia is actually suited for all pediatric and adult open heart procedure, particularly for adult coronary artery bypass operations when acute or critical obstruction of coronary arteries exists [4–7]. Nonetheless, the intramyocardial delivery and distribution of retrograde cardioplegic solution in human heart has remained sparsely documented [8,9]. In order to clarify those of retrograde cardioplegic solution in human, we thought that it was necessary to assess those of antegrade cardioplegic solution in the same patients and to compare with each other. Myocardial contrast echocardiography has enabled the assessment of intramyocardial distribution easily and repeatedly [10–12].
The objective of the present study was to assess the intramyocardial delivery and distribution of retrograde cardioplegic solution and compare it with the delivery and distribution of the solution in the conventional, antegrade fashion using myocardial contrast echocardiography during surgery.

2. Methods

2.1. Study population

Patients, 15, were studied by means of myocardial contrast echocardiography during surgery. Informed consent for the procedure was obtained from all patients. The 15 patients included five females and ten males whose average age was 61 ± 8 years old. Nine patients had valvular heart diseases, including two patients with aortic stenosis, two patients with aortic regurgitation, and five patients with mitral regurgitation. Six patients had coronary artery diseases, which included two patients with old myocardial infarcted areas and two patients with areas supplied by coronary collateral situation associated with totally occluded coronary arteries without myocardial infarction.

Surgery was performed under cardiopulmonary bypass via ascending aorta and right atrial double cannulas. For myocardial protection, moderate systemic hypothermia, topical ice slush (4°C) and cold blood cardioplegic solution were applied. After the initiation of cardiopulmonary bypass and occlusion of the ascending aorta, induction of cardioplegia was initially accomplished via aortic root (antegrade). However, with aortic valvular disease, induction of antegrade cardioplegia was accomplished via coronary tip. Immediately after infusion of antegrade cardioplegic solution, mild suction was placed on the aortic vent and cardioplegic solution was administrated retrogradely through a transatrial cannula with a balloon (DLP, Grand Rapids, MI.). The transatrial cannula was inserted into the coronary sinus by small right atriotomy. Coronary sinus perfusion pressure was monitored during retrograde delivery of cardioplegic solution and kept at a level of 40 mmHg (Flow = 150–200 ml/min). Anesthetic management was not modified during any phase of the anesthetic period. Similarly, surgical technique was not modified except during the period of contrast injections.

Sonicated 5% human albumin, 4 ml, was injected into the antegrade or retrograde cardioplegia lines through the stopcock by an assistant surgeon. The sonicated albumin was carried into the myocardium with the cardioplegic solution. Sonication was performed by a surgeon with a commercially available sonicating system (Sonifier model 250, Branson, Danbury, CT). Some injections were repeated.

Two-dimensional epicardial echocardiographic images were obtained using a commercially available phased-array system (model SSH-60A ultrasound system, Toshiba, Tokyo, Japan) with a 5 MHz transducer. Myocardial contrast echocardiography was performed by imaging an epicardial short-axis view at the midpapillary muscle level of the left ventricle. Echocardiographic images were recorded by a videotape recorder (model BR 5610, Victor, Tokyo, Japan) immediately before and for 1 min after each injection of contrast medium. Gain settings were adjusted at the beginning of each recording and were not changed during the remainder of the study.

2.2. Analysis of myocardial contrast echocardiography

We analyzed the contrast echocardiographic images as previously described [12]. A commercially available microprocessor-based off-line echocardiographic view system was used that consisted of a personal computer (model PC-9801, NEC, Tokyo, Japan) and a high-speed image processor capable of digitizing the echocardiographic field (model 68 322 and 64 000, Nexus, Tokyo, Japan). This system was used to convert two-dimensional echocardiographic images on the videotape to a 512 × 512 pixel matrix image with 256 grey levels per pixel and to quantify the intensity of echographic signals in the regions of interest. Each value of the intensity of myocardial enhancement was used as the value subtracted from the value before injection of the contrast agent. The region of interest was defined as the areas in the anterior wall, lateral wall and posterior wall of the left ventricle. Regions of interest were traced by hand. So that regional myocardial blood flow distribution could be assessed. Each area was divided into two layers, that is, epicardial and endocardial halves, and the intensities were measured for the same area in each half. The ratio of endocardial to epicardial intensity (endocardial/epicardial intensity ratio) was calculated.

2.3. Statistical analysis

All data were expressed as mean ± S.D. The non-parametric Wilcoxon method was used to compare the values.

3. Results

Contrast-enhanced images of regional myocardial delivery of cardioplegic solution were easily assessed in the left ventricle, but it was difficult to obtain reliable good images of all the right ventricle. No changes in any of the patients during myocardial contrast echocardiography were observed.
3.1. Valvular heart disease

Antegrade cardioplegic solution was distributed homogeneously, but retrograde cardioplegic solution was distributed less homogeneously (Fig. 1). Moreover, antegrade cardioplegic solution was delivered into all the left ventricle, while retrograde cardioplegic solution did not reach the midportion of the interventricular septum in six patients (6/9 = 67%).

Transmural myocardial distribution of both antegrade cardioplegic solution and retrograde cardioplegic solution were similar in the anterior wall (endocardial/epicardial ratio = 1.31 ± 0.24, 1.29 ± 0.26, respectively, NS), lateral wall (1.19 ± 0.05, 1.36 ± 0.23, respectively, NS), and posterior wall (1.33 ± 0.28, 1.44 ± 0.35, respectively, NS) of the left ventricle. In all the walls, endocardial/epicardial intensity ratio was more than 1, so that endocardial halves were significantly better reached than epicardial halves (Table 1).

3.2. Coronary heart disease

Neither antegrade nor retrograde cardioplegic solution were delivered to myocardial infarcted areas. Antegrade cardioplegic solution was not delivered to the area supplied by coronary collateral situation associated with totally occluded coronary arteries without myocardial infarction. However, such areas were reached well by retrograde cardioplegic solution (Fig. 2 and Fig. 3).

3.3. Delivery to the right ventricle

The existence of the small cardiac vein was important. In the patients where the venous phase of preoperative coronary arteriography revealed small cardiac vein, the delivery to the right ventricle dorsal walls was observed.

4. Discussion

Retrograde cardioplegia has become increasingly popular as an adjunctive method to provide myocardial protection during cardiac surgical procedures. However, relatively little information in human is available on the intramyocardial distribution of cardioplegic solution delivered through the coronary sinus [8, 9]. In the present study, we induced both antegrade and retrograde cardioplegic solution in the same patients in order to clarify the difference of intramyocardial delivery and distribution between antegrade and retrograde cardioplegic solution. We found that the distribution in the left

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<th>Antegrade method</th>
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<tr>
<td>Anterior wall</td>
<td>1.31 ± 0.24</td>
<td>1.29 ± 0.26</td>
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<tr>
<td>Lateral wall</td>
<td>1.19 ± 0.05</td>
<td>1.36 ± 0.23</td>
<td>NS</td>
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<tr>
<td>Posterior wall</td>
<td>1.33 ± 0.28</td>
<td>1.44 ± 0.35</td>
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Comparison between antegrade and retrograde cardioplegic solution in the nine patients with valvular heart disease. NS, not significant.
ventricle of retrograde cardioplegic solution was less homogeneous than that of antegrade cardioplegic solution, and was less in the midportion of the interventricular septum and in the right ventricle. However, transmural distribution of retrograde cardioplegic solution in the left ventricle was better in the endocardial halves, being similar to that of antegrade cardioplegic solution. In addition, in some patients with coronary artery disease, who had the areas supplied by coronary collateral situation associated with totally occluded coronary arteries without myocardial infarction, we could demonstrate that retrograde cardioplegia serves better.

Myocardial contrast echocardiography can assess myocardial perfusion including transmyocardial distribution easily and repeatedly even during cardiac surgical procedures [10–12], impossible with other methods using microspheres. We could assess the intramyocardial delivery and distribution in both ante-and retrograde cardioplegic solution in the same patients during the same operation. Furthermore, because we used sonicated albumin microbubbles as ultrasonic contrast agent, which behave like intravascular tracers of red blood cell flow [13].

We think that it is necessary to grasp the anatomy of coronary venous systems, which has marked variation, in the individual patients. Tschabitscher M [14] investigated the anatomy of the cardiac vein systems. According to their investigation, the anterior one-third of the interventricular septum was perfused through the anterior interventricular vein (= great cardiac vein), while the posterior one-third of the septum was perfused through the posterior interventricular vein in human. The middle one-third was perfused through smallest veins which do not drain into coronary sinus. These data supports our results, that is no perfusion of the midportion of the interventricular septum in 67% of our patients. In addition, they mentioned that the diaphragm wall of the right ventricle is drained by the posterior interventricular vein, and the anterior wall of the right ventricle is drained by the anterior interventricular vein (= great cardiac vein) and anterior cardiac vein. The dorsal wall of the right ventricle is drained by the small cardiac vein which drains into coronary sinus, or by small veins directly drain into right atrium. They reported that the existence of the small cardiac vein only in 25% of all cases. Accordingly, the perfusion of the dorsal wall of the right ventricle from the coronary sinus was supposed to be absent in 75% (66% in our study, because as the small cardiac vein was found in only 34% of 35 consecutive patients, as was assessed by the venous phase of coronary arteriography) of all patients.

Myocardial protection was poor in the areas supplied by coronary collateral situation associated with totally obstructed or severely stenosed coronary arteries [5,7]. Indirectly, it has been demonstrated that retrograde infusion may be an effective means of inducing cardioplegia in patients with normal or severely diseased coronary arteries [4,6]. We could visually show that antegrade cardioplegic solution was not distributed in areas supplied by coronary collateral situation associated with totally occluded coronary arteries, while retrogradely delivered cardioplegic solution was well distributed.

Several experimental studies have reported that retrograde cardioplegia results in poor perfusion of the interventricular septum and right ventricular myocardium using various methods [15–19], which agreed with our findings.

However, in human, Gates et al. [8] assessed retrogradely delivered cardioplegic solution by means of a technique to quantitatively demonstrate capillary perfusion. There was no significant difference in the percentage of capillaries perfused by retrogradely delivered cardioplegic solution between corresponding regions of the left and right ventricle. Aronson et al. [9] demonstrated that retrograde delivery of cardioplegic solution
reaches all the left ventricular myocardial regions, including the intraventricular septum using myocardial contrast echocardiography during surgery. Those results were different from ours. Gates et al. themselves stated that their study was static observation and that an ex vivo model might be somewhat inaccurate. Aronson et al. used sonicated Renografin-76 as ultrasonic contrast agent. The sizes of the microbubbles of sonicated Renografin-76 were relatively large [20]. Our different findings can be explained by the differences in microbubble size and concentration. The larger microbubbles used by Aronson et al. are trapped in the coronary circulation, and video intensity would be changed.

In order to improve the delivery of retrograde cardioplegia based on the present study, we think that it is necessary to fully grasp the coronary arterial and venous anatomy in individual patients. In addition, the positioning of the coronary sinus cannula is important with myocardial contrast echocardiography having proven useful in ascertaining the positioning of the cannula tip [21]. In order to obtain good delivery to the right ventricle, it is important to infuse the posterior interventricular vein and small cardiac vein when found. Fundamentally, we have to understand that the perfusion of the midportion of the interventricular septum is insufficient in some patients and the perfusion of the right ventricle is poor in most patients. We recommend antegrade cardioplegia for patients with poor right ventricular function. On the other hand, we recommend retrograde cardioplegia not only for those patients with areas supplied by coronary collateral situation associated with totally occluded coronary arteries but also in patients with left main trunk disease, based on our observation that retrograde cardioplegia is better in the areas supplied by coronary collateral situation associated with totally occluded coronary arteries.

5. Conclusions

The delivery to the left ventricle of retrograde cardioplegia was more heterogeneous than that of antegrade cardioplegia, and was less in the midportion of the interventricular septum and in the right ventricle. Transmural distribution of the left ventricle of retrograde cardioplegia was significantly better in the endocardial halves similar to that of antegrade cardioplegia. In addition, retrograde cardioplegic solution was better delivered to the areas supplied by coronary collateral situation associated with totally occluded coronary arteries. For delivery to the right ventricle, the existence of the small cardiac vein was important. These results have important implications for planning strategies of myocardial protection during surgery. We think that the use of combined cardioplegia was preferable in some patients with coronary artery disease, for example with totally occluded coronary arteries and/or severe stenosed coronary arteries. It goes without saying that we must fully grasp the coronary arterial and venous anatomy in individual patients.

References


