Spatial Relationship of the Left Ventricle in the Supine Position and the Left Lateral Tilt Position (Implication for Cardiopulmonary Resuscitation in Pregnant Patients)

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ABSTRACT

Application of the left lateral tilt position has been recommended during cardiopulmonary resuscitation (CPR) of pregnant patients. However, the left lateral tilt could displace the left ventricle (LV) besides the gravid uterus and may compromise the cardiac pump mechanism of CPR. Thus, we investigated the effect of left lateral tilt on the spatial relationship between the anterior-posterior axis (AP axis), which represents the direction of sternal displacement during CPR, and the LV. We retrospectively reviewed the medical records and multidetector computed tomography (MDCT) scans of 90 patients who underwent virtual gastroscopy using MDCT. Virtual gastroscopy was performed with the patient both in the left lateral tilt position and in the supine position. On an axial image showing the maximal area of the LV, the angle between the AP axis and the LV axis (AngleAP-LV), the shortest distance between the AP axis and the mid-point of LV cavity (DAP-MidLV), and the shortest distance between the AP axis and the LV apex (DAP-Apex) were measured. In the supine scans, the LV was situated on the left side of the AP axis in 87 patients (96.7%). On the left lateral tilt scans, the mean tilt angle was 43.4±11.0o. DAP-MidLV and DAP-Apex were significantly longer in the left lateral tilt position (p<0.001), but AngleAP-LV was comparable between the positions. This study indicates that the left lateral tilt position may compromise the cardiac pump mechanism of chest compression in pregnant cardiac arrest patients.

Keywords : Heart arrest, Cardiopulmonary resuscitation, Pregnancy, Patient positioning
1. Introduction

Cardiac arrest in pregnancy is a rare obstetric emergency(1). Although pregnant women are generally younger than typical cardiac arrest patients, the survival rate is worse in pregnant cardiac arrest patients(2). In late pregnancy, the gravid uterus causes vena caval compression in the supine position which may result in decreased venous return and cardiac output(3), and may negatively affect the cardiac output produced by chest compressions. Thus, relief of caval compression during cardiopulmonary resuscitation (CPR) is crucial for survival. The left lateral tilt position has long been used to alleviate caval compression by displacing the gravid uterus laterally. Several studies in non-cardiac arrest pregnant patients indicate that left lateral tilt position improves blood pressure and cardiac output(4,5).

Currently, there are two theories to explain the mechanism of forward blood flow during CPR; the cardiac pump theory and the thoracic pump theory(6,7). Several previous studies have suggested that the cardiac pump, rather than the thoracic pump, is the dominant mechanism in generating forward blood flow during CPR(7-9). According to the cardiac pump theory, compression of the left ventricle (LV) at the level of maximal diameter is required for effective CPR(7,10).

The current CPR guidelines recommend the application of the left lateral tilt position during CPR of pregnant patients, based on previous studies in non-cardiac arrest pregnant patients(11). No study has determined that the left lateral tilt position could maintain cardiac output during CPR similar to that which occurs in the supine position. From the view point of the cardiac pump, the left lateral tilt could displace the LV as well as the gravid uterus, and, thus, may compromise the cardiac pump. To our knowledge, no study has evaluated the effect of left lateral tilt on the position of the LV.

In this study, we sought to investigate the effect of left lateral tilt on the spatial relationship between the anterior-posterior axis (AP axis), which represents the direction of sternal displacement by chest compression, and the LV.

2. Methods

This study was approved by the Institutional Review Board of Chonnam National University Hospital (CNUH-2012-067). We retrospectively reviewed the medical records and multidetector computed tomography (MDCT) scans of patients who underwent virtual gastroscopy using MDCT as an evaluation for gastric cancer between January 2008 and December 2011 in our hospital. According to our institutional protocol, virtual gastroscopy was performed first with the patient in the left lateral tilt position by placing a rolled blanket under the right side of trunk to facilitate evaluation of gastric angle and antrum, then with the patient in the supine position. Exclusion criteria were as follows: severe chest deformity such as funnel chest, presence of conditions that could shift mediastinal organs including atelectasis, pleural effusion, large amount of ascites, and space-occupying mass within thoracic cavity and previous thoracoabdominal surgery. We also excluded patients whose CT scan did not cover the LV at the level of maximal area.

Demographic data, height and weight of the patients were obtained from medical records. The CT used in this study was Somatom Sensation Cardiac 64 and SOMATOM Definition Flash (Siemens Medical Solutions, Malvern, USA). The picture archiving and communication system (MAROSIS Maroview, Marotech Inc., Seoul, Korea) was used to analyse the images. We selected an axial image showing the maximal area of the LV in both the supine and left lateral tilt scans, respectively. At the axial image, an
imaginary line (Line_{Mitral}) was drawn between the points of mural attachment of the mitral valve leaflets (Figure 1). LV axis was defined as a line between the mid-point of the Line_{Mitral} and the LV apex. Point_{MidLV} was defined as a mid-point of the LV axis.

The AP axis was defined as a line passing through the sternum to represent the direction of sternal displacement during chest compressions, which was perpendicular to the horizontal plane in the supine position or perpendicular to the tilted plane in the left lateral tilt position, respectively. The tilt angle was defined as an angle between the horizontal plane and the tilted plane of the thoracic cage. The relationship between the AP axis and the LV was evaluated in the axial image of supine scans. With these definitions, the following are measured respectively in the supine and the left lateral tilt images: Angle_{AP-LV} (angle between the AP axis and the LV axis), D_{AP-MidLV} (shortest distance between the AP axis and the Point_{MidLV}), D_{AP-Apex} (shortest distance between the AP axis and the LV apex). The differences in Angle_{AP-LV}, D_{AP-MidLV} and D_{AP-Apex} between the supine and the left lateral tilt positions were calculated and defined as delta-Angle_{AP-LV}, delta-D_{AP-MidLV} and delta-D_{AP-Apex}, respectively.

Data were analysed using SPSS 15.0 (Chicago, IL, USA). Continuous variables were investigated for normality using the Shapiro-Wilk test. Normally distributed continuous variables were summarised as means and standard deviations (SD). The paired t test was conducted to compare between the two positions. Non-normally distributed continuous variables were summarised as medians with interquartile ranges. Categorical variables were summarised as frequencies and percentages. Pearson’s correlation was used to examine the relationships between the tilt angle and the delta values. Significance was set at p<0.05.

Table 1. Spatial Relationship between the Left Ventricle and the Antero-posterior Axis Passing through the Sternum

<table>
<thead>
<tr>
<th></th>
<th>Supine (n=90)</th>
<th>Left lateral tilt (n=90)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle_{AP-LV}, o</td>
<td>41.0±8.9</td>
<td>40.5±8.5</td>
<td>0.364</td>
</tr>
<tr>
<td>D_{AP-MidLV}, mm</td>
<td>48.9±7.8</td>
<td>59.7±8.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>D_{AP-Apex}, mm</td>
<td>76.9±11.4</td>
<td>87.7±11.4</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Angle_{AP-LV} angle between the AP axis and the LV axis; D_{AP-MidLV}, shortest distance between the AP axis and the Point_{MidLV}; D_{AP-Apex}, shortest distance between the AP axis and the LV apex.

Table 2. Correlation between the Tilt Angle and delta-Angle_{AP-LV}, delta-D_{AP-MidLV} and delta-D_{AP-Apex}

<table>
<thead>
<tr>
<th></th>
<th>r</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>delta-Angle_{AP-LV}, o</td>
<td>-0.52±5.39</td>
<td>-0.016</td>
</tr>
<tr>
<td>delta-D_{AP-MidLV}, mm</td>
<td>10.78±5.42</td>
<td>0.041</td>
</tr>
<tr>
<td>delta-D_{AP-Apex}, mm</td>
<td>10.87±5.95</td>
<td>0.066</td>
</tr>
</tbody>
</table>

had at least some of the LV cavity located below the sternum. On the left lateral tilt scans, the mean tilt angle was 43.4±11.0°. The spatial relationship between the LV and the AP axis in both positions is shown in Table 1.

D_{AP-MidLV} and D_{AP-Apex} were significantly longer in left lateral tilt position (p<0.001), but Angle_{AP-LV} was comparable between the positions. The tilt angle did not show a significant correlation with delta-Angle_{AP-LV}, delta-D_{AP-MidLV} and delta-D_{AP-Apex}, respectively (Table 2).

The differences in Angle_{AP-LV}, D_{AP-MidLV}, and D_{AP-Apex} between the supine and the left lateral tilt positions were defined as delta-Angle_{AP-LV}, delta-D_{AP-MidLV} and delta-D_{AP-Apex}, respectively.

4. Discussion

In this study, the LV was located more laterally in the left lateral tilt position compared with the supine position. This finding indicates that the left lateral tilt position may compromise the cardiac pump mechanism in pregnant cardiac arrest patients. Thus, the benefit of the left lateral tilt position on maintaining venous return may be offset by its deleterious effects on the cardiac pump mechanism.

Apart from the possible deleterious effects on the cardiac pump mechanism, the left lateral tilt position in pregnant cardiac arrest patients may have several other drawbacks. Tilting a pregnant patient during CPR may require interruption of chest compression and it is well known that interruptions in chest compressions affect resuscitation out-
comes adversely\(^{12}\). The left lateral tilt may also affect the quality of the chest compressions, because the direction of chest compression forces is not perpendicular to the horizontal plane. In a study by Rees and Willis, which assessed the efficacy of chest compressions with a manikin at various angles of inclination in the left lateral tilt, the chest compression force decreased as the angle of inclination of the plane increased\(^{13}\). They also reported that the manikin tended to slide off the incline plane at angles above 30\(^\circ\). Several recent studies have indicated that manual left uterine displacement in the supine position is as effective as the left lateral tilt in relieving caval compression\(^{14,15}\). For these reasons, the present guidelines recommend performing manual left uterine displacement in the supine position before placing the patient in a left lateral tilt position\(^{11}\). The findings of this study also suggest that the manual leftward displacement of the gravid uterus, rather than the left lateral tilt, should be used as an initial method to relieve caval compression during CPR.

There are several limitations to this study. First, this study could not demonstrate either the haemodynamic effects of left lateral tilt positioning or the effect on resuscitation outcomes. Thus, more studies are needed to validate our findings regarding whether or not the left lateral tilt affects resuscitation outcomes adversely. Second, our study patients were not women in late pregnancy. Late pregnancy, by itself, may affect the spatial relationship of LV. Third, because the CT scans were not taken during CPR, this study did not give realistic information during CPR.

5. Conclusions

Despite its limitations, the present study indicates that the left lateral tilt position may compromise cardiac pump mechanism of chest compression in pregnant cardiac arrest patients. Further study is required to reach a decisive conclusion on the clinical effects of left lateral tilt positioning during CPR in pregnant women.

6. Conflict of Interest

The authors have no conflict of interest.

References

13. G. A. Rees and B. A. Willis, “Resuscitation in Late Preg-