MR IMAGING OF DIAPHRAGMATIC MOTION: EFFECT OF POSITIONS IN NORMAL SUBJECTS

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Introduction

Dynamic MRI has been utilized to assess diaphragmatic motions in several studies [1,2]. However, their results were conflicting, hence, it is still in argument whether there are differences between right and left lungs in the hemidiaphragmatic excursion. All of those studies were done in supine position although it is known that the pulmonary ventilation and perfusion alter by body positions [3]. The objective of this study was to assess hemidiaphragmatic motions during breathing by means of dynamic MRI in different positions: supine, prone, and right and left decubitus.

Methods and Materials

Eight healthy male volunteers were scanned using a 1.5T body MR scanner (Signa Twinspeed, GEMS, Milwaukee, Wis) with a torso coil. After the localizer imaging, dynamic MRI was performed on the coronal image plane including the trachea using Fast Imaging Employing Steady-state Acquisition with the following parameters: TR = 3.2 msec, TE = 1.5 msec, FA = 45 °, FOV = 35 cm, matrix size = 224x224, slice thickness = 15 mm and NEX = 2, total scan time of 1.4 sec per image. The subjects were instructed to repeat the breathing slowly and deeply every 28 seconds to archive the maximum inspiration and expiration. Imaging was started to afford 50 images sequentially in four different positions. The highest point of each diaphragm was plotted against the time through the respiratory cycle. The maximum diaphragmatic displacement was measured in individual diaphragm as the diaphragmatic excursion. Further, we assessed the 'synchronicity' and 'velocity' of right and left hemidiaphragmatic motions quantitatively as follows: We calculated the relative time (P_{50}) to the entire expiration or inspiration time where 50% of the diaphragmatic displacement to the maximum excursion was completed. If the P_{50}s were same, right and left diaphragmatic motion could be determined as 'synchronized'. For the assessment of 'velocity', the velocity was measured from the steepest linear portion since a typical diaphragmatic motion is non-linear where it starts slowly, accelerates and slow down to complete the respiration process.

Results and Discussion

The diaphragmatic excursion of the right lung was significantly larger than that of the left lung in supine, prone and right decubitus positions whereas the right and left excursion were not different in left decubitus (Table 1). In both expiratory and inspiratory phases, P_{50} values of the right and left diaphragms were not significantly different in the prone and supine positions, implying that both hemidiaphragms moved synchronously. On the other hand, P_{50} values of the right and left diaphragms were 33.2 ± 4.1 and 54.9 ± 10.0 ($p<0.0001$) in right decubitus, and 63.6 ± 11.8 and 29.6 ± 7.9 ($p<0.0001$) in left decubitus, respectively, in expiration. In contrast, they were 53.3 ± 12.0 and 9.9 ± 12.8 ($p<0.05$) in right decubitus, and 38.0 ± 12.2 and 55.0 ± 13.7 ($p<0.05$) in left decubitus in inspiration. Thus, the dependent diaphragm completed the expiration process earlier whereas it completed the inspiration process later than the non-dependent side. In both respiration phases, there was no difference in the velocity between the right and left diaphragm in the prone and supine positions (Table 2, 3). In decubitus positions, the velocity of the dependent diaphragm was larger than that of the non-dependent diaphragm in expiration phase whereas there was no difference between both hemidiaphragms in inspiration phase.

It is known that diaphragm is moved passively by abdominal pressure and ribcage movement during expiration. In contrast, diaphragm moves actively during inspiration, which is innerved by two phrenic nerves. In dependent side, the abdominal pressure is increased, the chest wall is compressed and the intrapleural pressure is less negative in decubitus position. The combination of those alterations might have contributed to deflate the lung easier, which resulted in earlier and faster hemidiaphragmatic movement as observed in both decubitus positions. By contrast, those alterations, except in the intrapleural pressure, could have resisted the inflation of the dependent lung. However, the velocity was maintained against the increased pressure in the dependent side since this motion is active in the inspiration phase although the P_{50} became larger.

Conclusion

The diaphragmatic motion was not significantly different between right and left sides in supine and prone positions. By contrast, in decubitus positions, the dependent diaphragm completed the expiration process earlier whereas it completed the inspiration process later than the non-dependent side. The velocity of the dependent diaphragm was larger than that of the non-dependent diaphragm in expiration phase whereas there was no difference between both hemidiaphragms in inspiration phase.

References 1. D. S. Gierada, et al., Radiology. 194:879 (1995), 2. K. Suga, et al., JMRI. 10:510 (1999), 3. J. B. West, et al., J Appl Physiol. 15:405 (1960)

Table 1. Diaphragmatic excursion (N = 8)

	Right (mm)	Left (mm)	*P*
Supine	88.9 ± 10.1	74.5 ± 11	0.046
Prone	93.0 ± 3.1	81.2 ± 6.2	0.017
Rt.Dec	91.3 ± 8.6	77.4 ± 11	0.031
Lt.Dec	83.6 ± 12.2	82.2 ± 11	0.44

Table 2. Velocity in expiration (N = 8)

	Right(mm/sec)	Left(mm/sec)	*p*
Supine	4.8 ± 1.4	4.8 ± 1.0	0.49
Prone	5.6 ± 3.1	5.2 ± 2.8	0.39
Rt. Dec	9.9 ± 3.8	5.2 ± 5.2	0.029
Lt. Dec	3.9 ± 2.4	7.7 ± 2.6	0.0043

Table 3. Velocity in inspiration (N = 8)

	Right(mm/sec)	Left(mm/sec)	*p*
Supine	7.6 ± 4.0	6.7 ± 2.8	0.31
Prone	5.4 ± 3.0	5.3 ± 2.6	0.49
Rt. Dec	8.3 ± 3.2	7.1 ± 4.4	0.28
Lt. Dec	7.5 ± 4.5	6.6 ± 3.2	0.34