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Case report

A novel sonographic sign of paradoxical movement of diaphragmatic paralysis in pediatric patients after cardiovascular surgery ☆

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ABSTRACT

We demonstrate a quick sliding of the descending aorta toward the unaffected side of the diaphragm as a new sonographic finding during breathing in pediatric patients with diaphragmatic paralysis. We present three pediatric patients with diaphragmatic paralysis after cardiovascular surgery with this new sonographic finding. This finding consisted of paradoxical movement of the diaphragm as shown by fluorography. This sonographic sign was only obtained by a B-mode scan in the subxiphoid plane, was easily demonstrated at the patient's bedside, and may be useful for diagnosing severe diaphragmatic paralysis.

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Introduction

Despite the progression of operative techniques, postoperative diaphragmatic paralysis is an unavoidable complication after cardiovascular surgery [1–3]. This complication is associated with difficult weaning from mechanical ventilation, respiratory insufficiency, and prolonged hospital stays [4,5]. A diagnosis of diaphragmatic paralysis is based on abnormal movement of the diaphragm as observed by sonographic and fluorographic imaging [6–9]. Diaphragmatic plication, which is more beneficial in young children than in adults, is a viable surgical intervention for this complication depending on the patient's clinical symptoms [2,4,6,10]; therefore the timely and accurate diagnosis of diaphragmatic paralysis is important.

Abnormal diaphragmatic movements in diaphragmatic paralysis include paretic, akinetic, and paradoxical movements [6,7], with paradoxical movements having the most

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severe clinical presentation [6]. By fluorography, paradoxical movement is diagnosed as retrograde movement compared to the movement of a nonparalyzed diaphragm, and with the mediastinum sliding into the unaffected side of the diaphragm [7,11]. By ultrasound, paradoxical movement is diagnosed as diaphragmatic movement away from the transducer during inspiration using the M-mode technique [6-8,12]. Mediastinal movement cannot be evaluated by ultrasound. In addition, cases in which the mediastinum slides into the unaffected side of the diaphragm were reported to require more time for spontaneous recovery from diaphragmatic paralysis compared to cases without this finding [13].

In this report, we focused on the movement of the descending aorta, which is one aspect of the mediastinum, and demonstrated three cases with various degrees of the quick sliding of the descending aorta into the unaffected side of the diaphragm by ultrasound, which may be a useful finding to diagnose paradoxical diaphragmatic movement.

This retrospective study was approved by the ethics committee of our institution, and informed consent was waived.

Case report

Case 1 is a 17-day-old female with left diaphragmatic paralysis who was born with type 2 transposition of the greater arteries. Surgical intervention was performed before 8 days of age. A routine radiograph demonstrated that the location of the left diaphragm was higher than that of the right side (Fig. 1a). Left diaphragmatic paralysis was suspected; therefore, ultrasound and fluorography were performed. B-mode ultrasound showed paralysis of the left diaphragm and a quick sliding of the descending aorta toward the right side during breathing (Fig. 1b and c). Fluorography showed paradoxical diaphragmatic movement (Fig. 1d and e). The mediastinum moved toward the unaffected side of the diaphragm during breathing. Diaphragmatic plication was performed due to recurrent respiratory distress 1 week after the examinations. After plication, the patient recovered from the respiratory distress and then discharged from our hospital.

Case 2 was a 3-month-old female with left diaphragmatic paralysis. This patient was born with double-outlet right ventricle and pulmonary atresia, and surgical intervention was performed before 8 days of age. A routine postoperative radiograph showed elevation of the left diaphragm, and diaphragmatic paralysis was suspected (Fig. 2a). Ultrasound with B-mode ultrasound revealed paralysis of the left diaphragm and a quick sliding of the descending aorta toward the right side of the diaphragm during breathing (Fig. 2b and c). Fluorography showed paradoxical diaphragmatic movement, and the paralytic and unaffected sides of the diaphragm moved in opposite directions during breathing (Fig. 2d and e). In addition, the mediastinum moved towards the unaffected side of the diaphragm during breathing. Paradoxical movement of the diaphragm was diagnosed. Diaphragmatic plication was performed because the patient's respiratory condition did not improve. Subsequently, patient's respiratory condition improved after the procedure.

Case 3 was a 11-month-old male with right diaphragmatic paralysis. This patient was born with double-outlet right ventricle, and surgical intervention was performed before 18 days of age. A chest radiograph obtained in the intensive care unit showed the right diaphragm located at a higher position compared to the left diaphragm (Fig. 3a). Right diaphragmatic paralysis was suspected, and was confirmed by ultrasound (Fig. 3b and c). In addition, a quick sliding of the descending aorta into the left side of the diaphragm (the unaffected side) was detected during breathing. Fluorography showed paradoxical diaphragmatic movement (Fig. 3d and e). During breathing, the unaffected left diaphragm moved downwards and the paralytic right diaphragm moved upwards. The mediastinum moved towards the unaffected side of the diaphragm during breathing. Diaphragmatic plication was performed because the patient's respiratory condition did not improve.

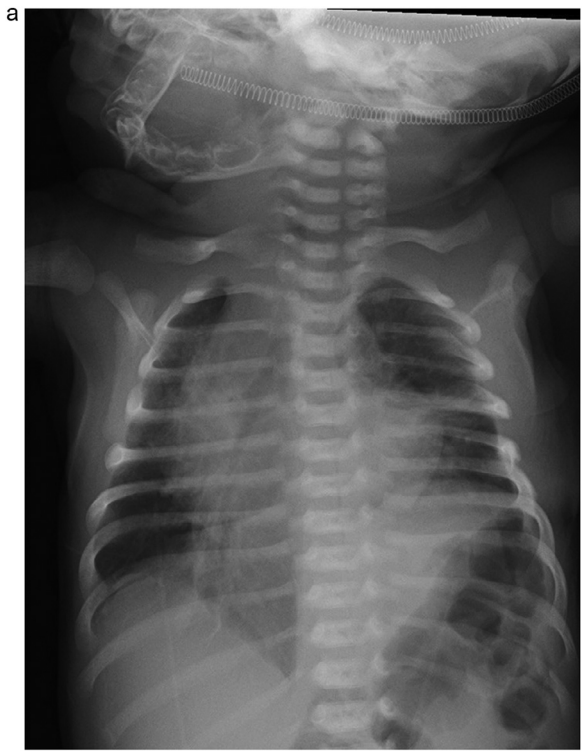

Fig. 1 – Case 1: A 17-day-old female with left diaphragmatic paralysis. (a) Routine radiograph demonstrated that the location of the left diaphragm was higher than that of the right side. (b, c) B-mode sonogram shows paralysis of the left diaphragm. Right panels are schematic presentations of the left panels. The left diaphragm did not move between exhalation (b) and inhalation (c). In addition, the quick sliding movement of the descending aorta towards the right side can be observed during inhalation (c) compared to the movement during exhalation (b). (d, e) Fluorography shows paradoxical movement of the diaphragm. Right panels are schematic presentations of the left panels. The mediastinum moved toward the unaffected right side during inhalation (e) compared to the movement during exhalation (d).

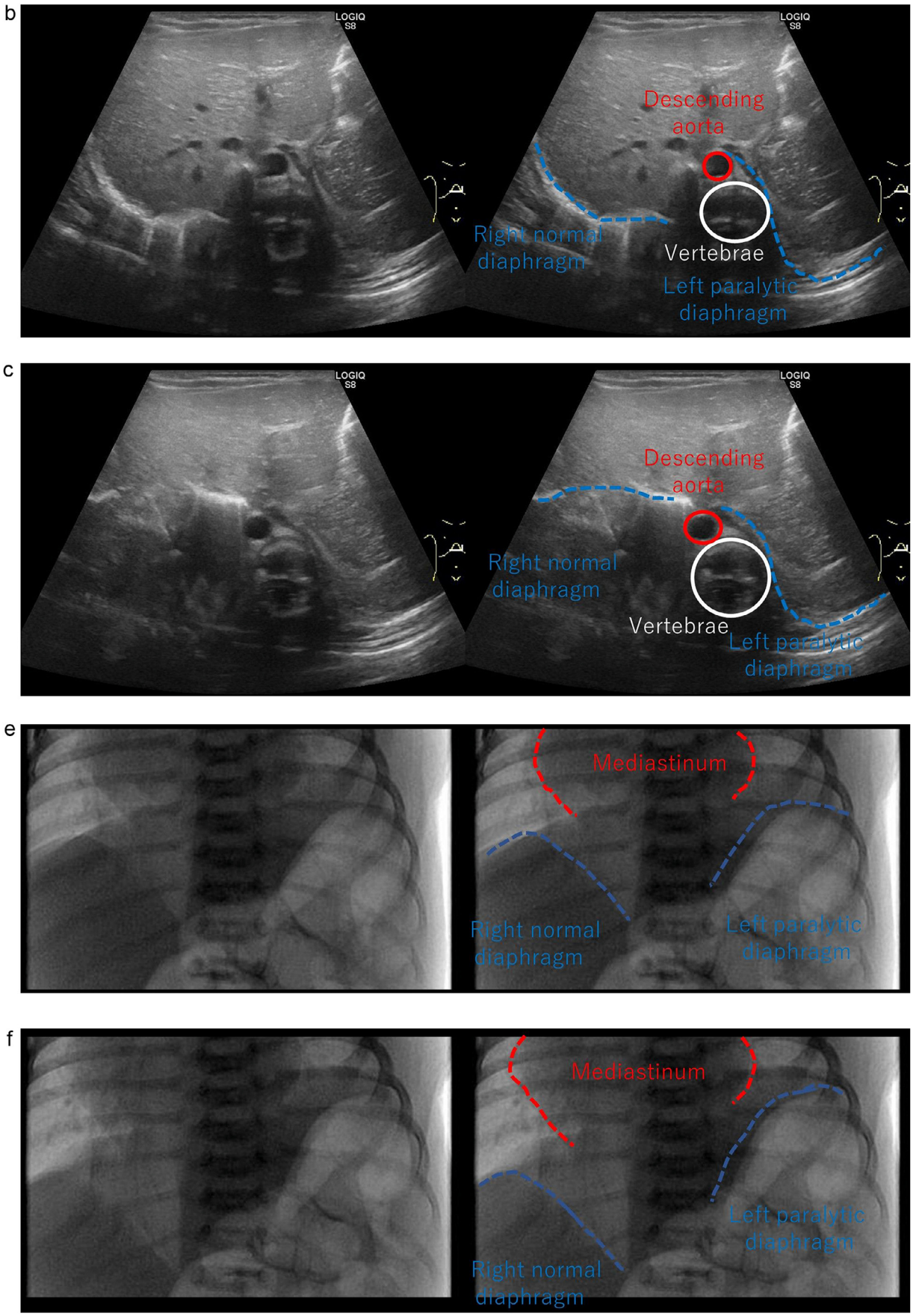

Fig. 1 – Continued

Subsequently, the patient's respiratory distress improved after plication.

All sonograms were obtained with a 9-15-MHz linear transducer (LOGIQ 7, E9, or S8; GE Healthcare, Waukesha, WI) via the B-mode scan in the subxiphoid plane. All patients were examined without specific preparations and in the supine position.

Discussion

We identified a quick sliding of the descending aorta toward the unaffected diaphragm side during breathing in pediatric patients with diaphragmatic paralysis. In a healthy patient, the descending aorta does not move and remains in the same position during breathing.

Although the diagnosis of paradoxical diaphragmatic movement was made by comparing diaphragmatic movement of the affected and unaffected sides using M-mode ultrasonography, our new sonographic sign was obtained by only the B-mode scan in the subxiphoid plane. Although the M-mode technique was useful, mediastinal movement could not be evaluated by this method. We focused on the movement of the descending aorta, which is one aspect of the mediastinum. Therefore, this new sonographic finding may be consistent with paradoxical mediastinal movement detected by fluorography. This sonographic finding was easily demonstrated at the bedside and may be useful in diagnosing severe diaphragmatic paralysis.

Diaphragmatic paralysis may result in exercise intolerance or recurrent pneumonia, and diaphragmatic plication may be needed as surgical repair of the diaphragm [14,15]. On the other hands, the incidence of spontaneous recovery from diaphragmatic paralysis after cardiovascular surgery has been reported to be 50%, with the timing of recovery varying from a few days to several months after surgery [4,11,16,17]. In addition, when pediatric patients with paradoxical movement of the diaphragm recovered from diaphragmatic paralysis, diaphragmatic movement changes from paradoxical to weak, and then finally becomes normal [2]. Therefore, a follow-up to determine the degree of diaphragmatic paralysis was important to prevent complications, and to decide whether to perform the diaphragmatic plication. In case 1, sliding of the

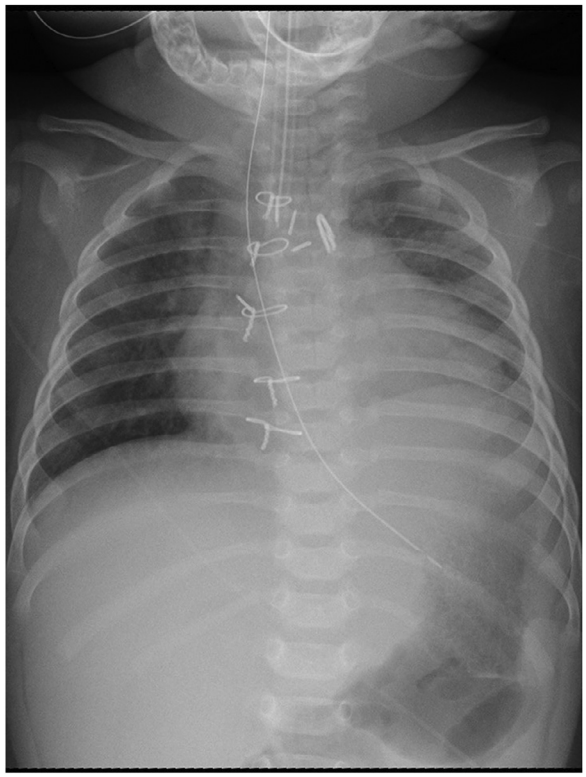

Fig. 2 – Case 2: A 3-month-old female with left diaphragmatic paralysis. (a) Routine radiograph shows elevation of the left diaphragm. (b, c) Exhalation (b) and inhalation (c). Right panels are schematic presentations of the left panels. B-mode ultrasound shows paralysis of the left diaphragm. In addition, the quick sliding movement of the descending aorta towards the right side can be observed during breathing. (d, e) Exhalation (d) and inhalation (e). Right panels are schematic presentations of the left panels. Fluorography shows paradoxical movement of the diaphragm as the unaffected and paralytic diaphragm sides move in opposite directions during breathing. In addition, the mediastinum moved slightly toward the unaffected right side during breathing. Paradoxical movement of the diaphragm was diagnosed.

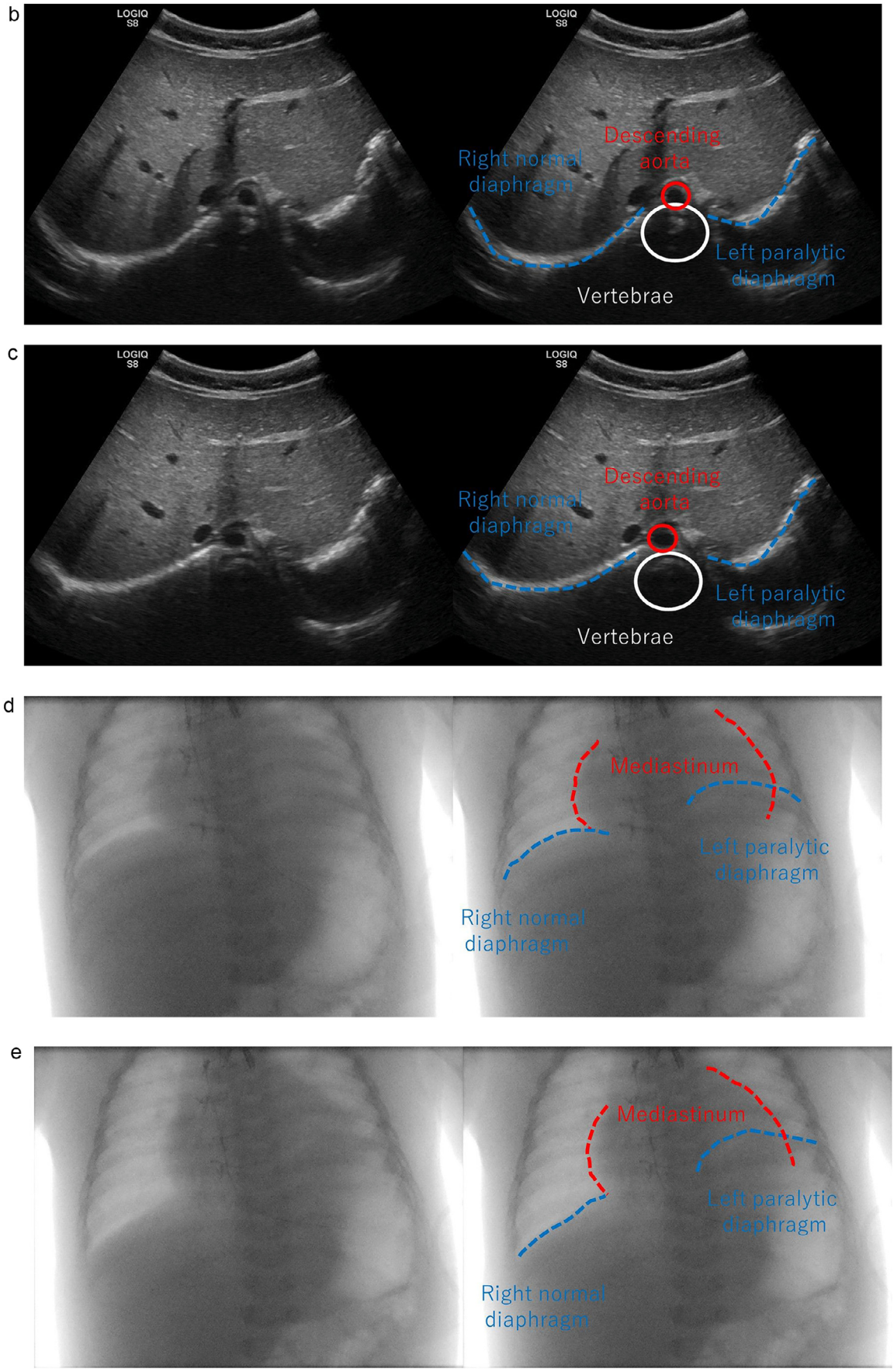

Fig. 2 – Continued

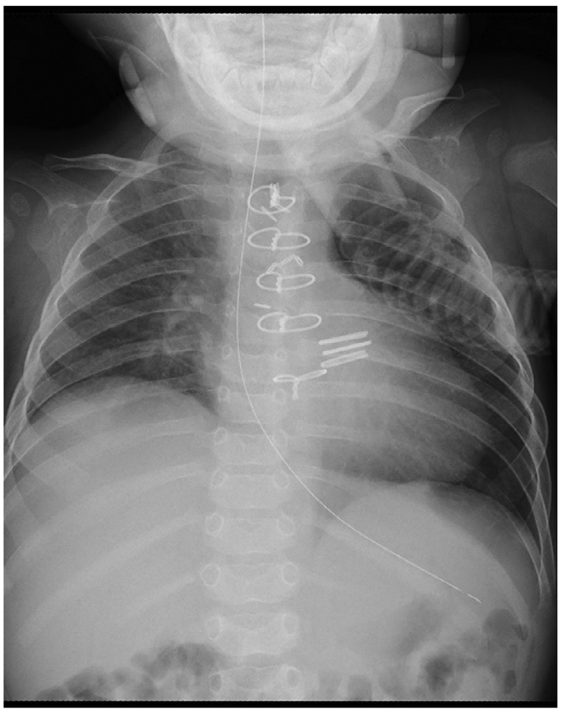

Fig. 3 – Case 3: An 11-month-old male with right diaphragmatic paralysis. Chest radiograph shows elevation of the right diaphragm. (b, c) Sonograms that obtained in the subxiphoid plane during breathing showing paralysis of the right diaphragm. Right panels are schematic presentations of the left panels. The location of the left diaphragm was unchanged upon exhalation (b) and inhalation (c). In addition, the quick sliding movement of the descending aorta toward the left side is shown upon inhalation (c) compared to exhalation (b).(d, e) Fluorography shows paradoxical movement of the diaphragm. Right panels are schematic presentation of left. During exhalation (d), the paralytic right diaphragm is located at a higher position than the left diaphragm. During inhalation (e), the right diaphragm moved slightly upwards and the unaffected left diaphragm moved downwards. The mediastinum moved towards the unaffected left side during inhalation (e) compared to the movement during exhalation (d).

descending aorta was more clearly visualized compared to that in case 2. In fluorography, a mediastinal shift was clearly visualized in case 1 compared to that in case 2. Therefore, the degree of sliding of the descending aorta during an ultrasound examination may be correlated with the degree of mediastinum shift in fluorography and may therefore be useful for the evaluation of diaphragmatic paralysis.

Fluorography is usually performed to diagnose diaphragmatic paralysis after cardiovascular surgery [6,7]. However, while this examination can easily reveal abnormal findings, it requires radiation exposure and cannot be performed at a patient's bedside. The latter is important because pediatric patients can sometimes have an unstable circulation status after cardiovascular surgery and are not to be moved from the intensive care unit. Therefore, easy sonographic exams without radiation exposure, and portable diagnosis of paradoxical diaphragmatic movement is beneficial to intensivists and pediatric surgeons in deciding whether or not to perform diaphragmatic plication.

The diaphragmatic paralysis was suspected on average 10 days after cardiovascular surgery. With this timing, it may be difficult to obtain the subxiphoid plane by an ultrasound examination because of the surgical devices or gauze on this site. To solve this problem, the approach to visualize the descending aorta could be changed. For example, the descending aorta could be visualized behind the heart if the image was obtained by using the parasternal view. In addition, coordination with intensive care unit staff/nurses is needed to facilitate these scans and acquiring images.

Conclusion

We present a new sonographic finding in pediatric patients with diaphragmatic paralysis consisting of a quick sliding of the descending aorta into the unaffected side of the diaphragm during breathing. This sonographic sign was obtained by only a B-mode scan in the subxiphoid plane, was easily demonstrated at the patient's bedside, and may be useful in diagnosing severe diaphragmatic paralysis.

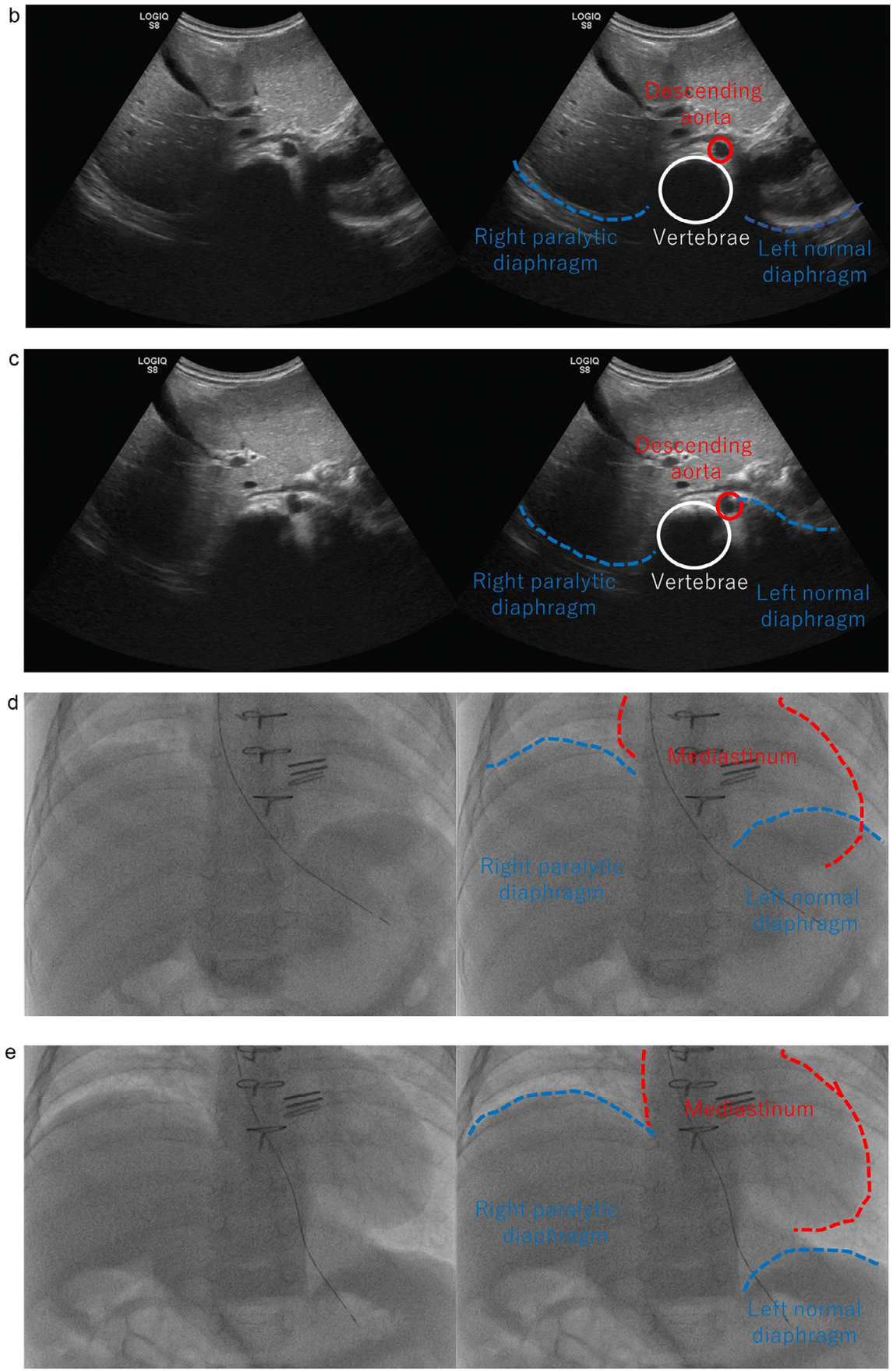

Fig. 3 – Continued

Research Involving Human Subjects

This research was performed in accordance with the tenets of the Declaration of Helsinki.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.radcr.2021.01.033.

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