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The Giant Post-Traumatic Diaphragmatic Hernia: Clinical Case and Literature Review

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ABSTRACT The post-traumatic diaphragmatic hernia is a rare type of trauma which most commonly occurs after the blunt trauma of the thorax and abdomen. In the acute period of trauma, the symptoms of the emergency diseases and nonspecific signs of the diaphragmatic rupture are the reasons of frequent diagnostic mistakes. A missed diaphragmatic rupture grows in time and leads to migration of organs from the abdominal cavity to the thoracic one due to pressure gradient. The symptoms of diaphragmatic hernia are not expressed and the duration of the asymptomatic period of the disease may vary from some years to 10 years and longer. The increasing restructuring of the abdominal wall leads to reduced abdominal cavity, which makes the standard reconstructive surgery difficult, the intra-abdominal pressure grows and relapse occurs in the postoperative period. In these cases, surgeons perform complex techniques which enlarge the abdominal cavity with local tissues or an artificial graft. However, there are no clear recommendations about the extent of the abdominal wall reconstruction so that the abdominal cavity size would be adequate for organs. The authors suggested a simple method to calculate it and used it in practice.

In the article, we report the clinical case of a 53-year-old woman with a giant post-traumatic diaphragmatic hernia after motor vehicle accident 48 years ago and offer an original method of treatment. The first operation including hernia resolution and repair of diaphragmatic rupture was complicated by relapse on the second day after operation due to the high intra-abdominal pressure. During the second reconstructive surgery (4 months later), the authors performed their own method of abdominal cavity enlargement and got a good result in the short- and long-term postoperative period.

Keywords: post-traumatic diaphragmatic hernia, diaphragmatic hernia, abdominal reconstruction, polypropylene mesh

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ACS — abdominal compartment syndrom
CT — computed tomography
GIT — gastrointestinal tract
IAP — intra-abdominal pressure
MSCT — multispiral computed tomography
PTDH — post-traumatic diaphragmatic hernia

Post-traumatic diaphragmatic hernia (PTDH) is the migration of abdominal organs into the pleural cavity through an opening in the diaphragm that occurs as a result of injuring the diaphragm or blunt trauma to the abdomen. It is a relatively rare disease. The formation of such a hernia occurs in about 5% of patients after a blunt abdominal injury [1]. In this case, the most frequent damage to the diaphragm occurs as a result of an accident or a fall from a height [2]. The left dome of the diaphragm is most often damaged, while the right dome covered by the liver is damaged only in 0.8–3.6% of cases [3]. Often, diaphragm damage remains unrecognized due to the absence of pathognomonic signs and the predominance of other symptoms associated with trauma. For this reason, the final diagnosis is established after a long period of time from the moment of damage up to several months or years.

Based on observations, the duration of PTDH and the volume of dislocated organs in the pleural cavity correlate with a change in the structure of the abdominal wall, as a result of which the latter adapts to a change in intra-abdominal pressure (IAP) and a decrease in the volume of the abdominal cavity. Lowering of organs from the chest to the abdominal cavity and closing the defect of the diaphragm leads to increased pressure in the abdominal cavity, the development of the abdominal compartment syndrome (ACS) and often a hernia recurrence. To prevent such complications, various methods of the anterior abdominal wall plasty with artificial materials are currently used. However, it is extremely difficult to determine the required volume of the abdominal cavity and, accordingly, the dimensions of the material. The method offered by the authors can significantly facilitate the implementation of this task.

Clinical case.

A 53-year-old female patient K. was admitted as planned to the Moscow Clinical Scientific Center of A.S. Loginov (MCSC) on September 4, 2014 with complaints of shortness of breath during exercise and lying down, as well as discomfort in the left half of the chest. Shortness of breath intensified after ingestion of food and fluid. In the supine position, shortness of breath was so strong that the patient was suffocating. For this reason, the patients has been forced to sleep in a sitting position for 5 years. From the anamnesis it is known that the patient aged 5 years received a blunt abdominal injury as a result of a car accident. No violations of the diaphragm were detected. It was treated conservatively and didn't seek medical assistance subsequently. Twice there was a normal urgent delivery without complications. Children are healthy.

Upon examination: proper constitution, moderate nutrition. The skin and mucous membranes were normal in color. Pulse 85–90 beats/m in, rhythmic. Blood pressure 130/80 mm Hg. The chest was symmetrical. The left half was somewhat behind in the act of breathing. Breathing in the standing position was not heard in the lower chest on the left, in the supine position - over the entire surface of the chest wall on the left. Peristaltic noises were clearly defined there. Upon percussion, a dull sound, or a boxed sound, was determined.

Chest X-ray in a front projection revealed the presence of loops of the colon and small intestine in the left pleural cavity, displacement of the mediastinum and deviation of the trachea to the right, flattening and deformation of the left dome of the diaphragm (Fig. 1). Severe violations in the work of the heart and lungs were not detected. In the sitting position, the ejection fraction of the left ventricle was 55%, while examining the function of external respiration, slight restrictive changes were revealed. The final diagnosis was set using multispiral computed tomography

(MSCT), which confirmed the presence of a defect in the left dome of the diaphragm and the presence of the entire stomach, left lobe of the liver, loops of the small and large intestine, spleen and tail of the pancreas in the left pleural cavity (Fig. 2) . Thus, the patient had lived with PTDH for 48 (!) years.

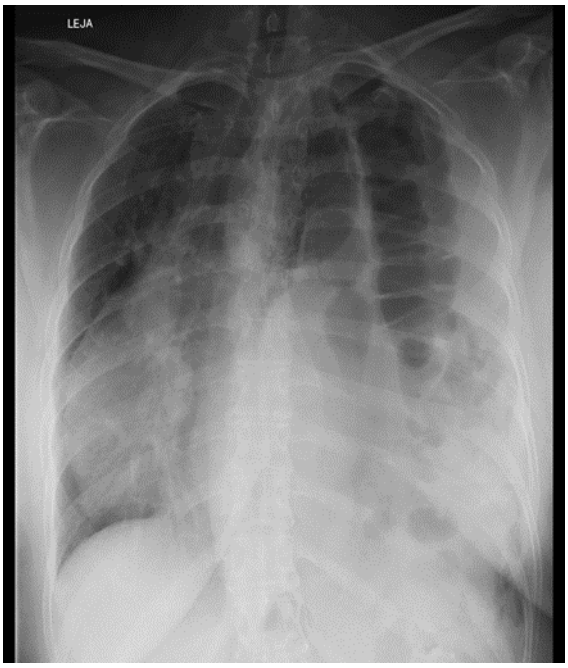

Fig. 1. Chest X-ray. Loops of the colon in the left pleural cavity, displacement of the mediastinum in the opposite direction, flattening and deformation of the left cupula of the diaphragm

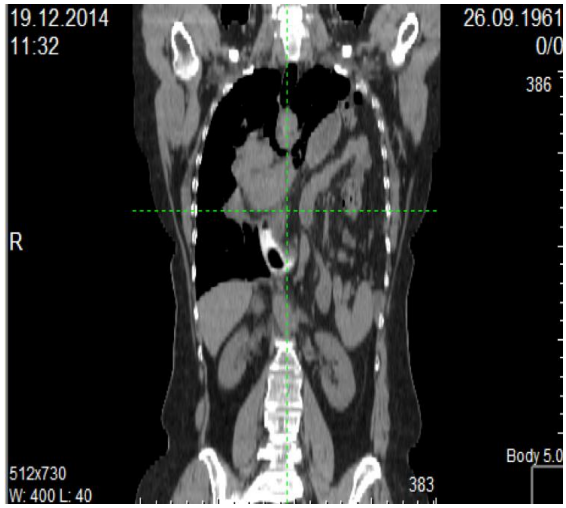

Fig. 2. CT scan of the organs of the thoracic and abdominal cavities. The hernial contents in the left pleural cavity are represented by the stomach, the left lobe of the liver, loops of the small and large intestine, spleen, and the tail of the pancreas

In the A.S. Loginov MCSC, the first surgical intervention through thoracoscopic access was performed on September 10, 2014. To facilitate the work in the left pleural cavity, a separate intubation of the bronchi was made. We managed to lower the displaced organs (stomach, left lobe of the liver, loops of the small and large intestines, spleen and tail of the pancreas) into the abdominal cavity, suture the defect in the diaphragm with interrupted sutures and cover this suture with a synthetic mesh. The movement of such a mass of organs into the abdominal cavity against the background of relaxation of the left dome of the diaphragm was possible, however, in the postoperative period led to a significant increase in IAP. This was the cause of the failure of the sutures on the diaphragm and hernia recurrence on the 2nd day after the operation. Since the patient's condition after that remained satisfactory, on the 8th day she was discharged from the hospital with a recommendation to undergo examination in 4-6 months to determine the tactics of further treatment. Five months later, a second examination was conducted. In this case, the X-ray picture and the picture of computed tomography (CT) remained approximately the same as during the first examination.

When choosing the method of the second operation, it became obvious that with such a giant hernia, it was necessary not only to restore the integrity of the diaphragm, but also to increase the volume of the abdominal cavity, creating space for displaced organs. Due to the long existence of a hernia, the abdominal cavity has decreased in volume due to the natural tone of the muscles. It is clear that to increase the volume of the abdominal cavity was possible only by increasing the surface of the anterior abdominal wall. Various options for such operations, which include plastic surgery of the anterior abdominal wall with their own tissues and synthetic materials, have been used for a long time. However, there are still no clear recommendations to correctly calculate the size and area of synthetic material to close the defect in the abdominal wall. In our case, it was important to determine the adequate area and dimensions of the synthetic prosthesis, since in the event of an error, the likelihood of the development of ACS and hernia recurrence increased. To eliminate this problem, the authors proposed an original method for determining the area of a synthetic prosthesis that replaces an abdominal wall defect.

We have constructed our reasoning as follows. As you know, the ball has the smallest surface with the largest volume. The abdominal cavity has the greatest resemblance to an ellipsoid, but for a practical solution to the problem it can be conditionally taken as a ball. It is also conditionally possible to take for the ball and the shape of a hernia that extends beyond the abdominal cavity. Using computed tomography (CT)

(Fig. 3), it is easy to determine the volume of the abdominal cavity (V_1), hernial protrusion (V_2) and their total volume ($V_3 = V_1 + V_2$). Moving the hernial contents into the abdominal cavity, we must create its volume equal to the specified total volume. To create this volume, we have to increase the area of the anterior abdominal wall by a certain amount in order to prevent its critical tension when covering the diaphragm defect.

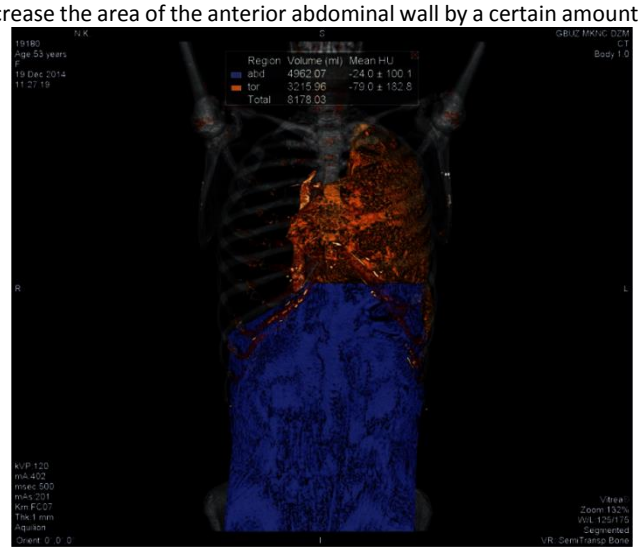

Fig. 3. CT scan of the chest and abdominal cavities. Determination of abdominal organs volumes (blue color) and hernial contents (orange color)

Using simple mathematical transformations, we created a formula for calculating the area by which the anterior abdominal wall should be increased to create the required final volume, which also corresponds to the size of the plastic material. This area is calculated by the formula, which is tied to only one indicator - the volume, which makes it simple for practical use: $S = 4.84 \cdot (V_3^{2/3} – V_1^{2/3})$.

The patient was repeatedly operated on January 1, 2015. After laparotomy incision and adhesions in the peritoneal cavity revealed that through a hole in the diaphragm diameter of approximately 13-14 cm into the pleural cavity of the stomach and moved all the greater omentum, a large number of fine loops intestines, as well as the spleen with the tail of the pancreas. It should be noted that the stomach, large omentum and loops of the colon and small intestine were fixed by adhesions to the walls of the pleural cavity. With technical difficulties, using a video camera, these adhesions were dissected and these organs were relegated to the abdominal cavity. A defect in the diaphragm was covered with the help of the release of mesh prosthesis by *Covidien*. Since, when moving to the abdominal cavity, the dome of the cecum turned out to be in mesogastrium, an appendectomy was made to exclude a diagnostic error in case of acute appendicitis in the patient. To reduce the volume of displaced organs, omentectomy was performed. Dor fundoplication was performed due to changes in the anatomical and topographic relative position of organs in the area of esophagogastric junction and a high risk of gastroesophageal reflux development.

Using the formula given above, the area of the mesh transplant was calculated, which we used to additionally strengthen the anterior abdominal wall after its plastic surgery according to V.I. Belokonev. V_1 was equal to 4962.07 cm^3, V_2 - 3215.96 cm^3 and V_3 - 8178.03 cm^3, respectively. Substituting these values into the formula, we obtained $S = 556.56$ cm^2. Thus, the mesh size was 23x24 cm.

To strengthen the anterior abdominal wall, we used a *Burd Soft Mesh* macroporous polypropylene mesh. In our case, the area of the mesh prosthesis was approximately equal to the area that was obtained with plastic surgery of the anterior abdominal wall according to V.I. Belokonev, therefore, the mesh turned out to be fixed just along the Spigelian line (Fig. 4). A wound on the abdomen was drained by Redon. The postoperative period was relatively smooth. Exudative pleurisy, which proceeded without an increase in body temperature, was eliminated by pleural punctures. Also, seroma in the area of the postoperative wound was punctured under the ultrasound guidance. The patient was discharged on the 16 th day .

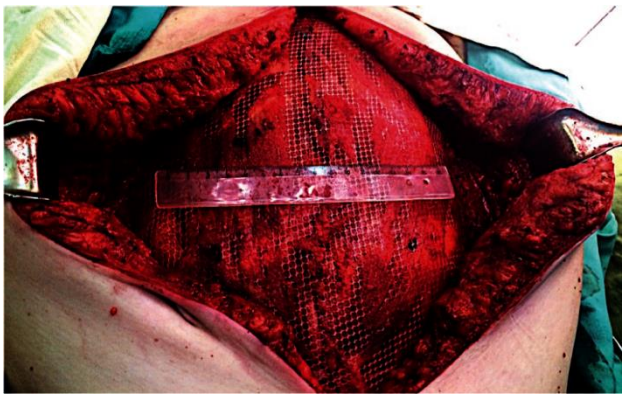

Fig. 4. Fixation of the graft along the Spigelian line for plastic surgery of the anterior abdominal wall according to V.I. Belokonev

The patient was examined 2 and 4 years after surgery. No complaints. Leads a normal lifestyle. Sleeps in a prone position. Diagnosed with a slight relaxation of the left dome of the diaphragm. The left lung is expanded, minor adhesions are determined on the diaphragmatic surface of its lower lobe. (Fig. 5,6)

Fig. 5. Chest and abdominal X-ray 4 years after treatment

Fig. 6. X-ray of the esophagus and stomach 4 years after treatment. No recurrent hernia revealed

DISCUSSION

Post-traumatic diaphragmatic hernias (PTDH) is an extremely heterogeneous group of diseases. Depending on the type of injury and the nature of the etiological factor, the tactics of clinical diagnostic and therapeutic measures will vary. With an open injury to the chest or abdomen, it is possible to follow the progress of the wound canal, perform an audit of the wound and, accordingly, diagnose damage to the diaphragm. Whereas with a closed injury, the diagnosis of rupture of the diaphragm is associated with certain difficulties. In accordance with the classification of traumatic hernias offered by *B.N. Carter* in 1951 [4], there are three stages of the development of the disease: acute (0–14th day after the injury), intermediate, or stage of late manifestations, and the stage of hernia contents strangulation. In the acute stage with damage to the organs of the chest and abdominal cavities in the clinical picture, the symptoms of shock prevail due to massive blood loss, impaired functioning of the heart, respiratory system and gastrointestinal tract (GIT). Moreover, damage to the diaphragm is often not detected [5; 6].

However, with large defects of the diaphragm and migration of abdominal organs into the pleural cavity, a hernia may be diagnosed in a hospital. In cases of a small defect, when displacement of organs is not observed, the establishment of the fact of damage to the diaphragm is an intractable task. Revealed signs during X-ray (high standing and limitation of mobility of the dome of the diaphragm) are nonspecific in nature [6, 7].

Unrecognized damage to the diaphragm progresses over time, which ultimately leads to an increase in the size of the defect and the formation of a hernia. Due to the lack of clinical symptoms, the duration of the hernia varies from several months to decades. So, in a study by *S. Singh et al.* [8] the longest duration of the disease was detected from the moment of injury to the admission to the hospital for a hernia of the diaphragm - 50 years.

As a rule, in the stage of late manifestations, the severity of clinical symptoms correlates with the volume and contents of the displaced organs. The most common sign of PTDH is a violation of the functions of the respiratory system (shortness of breath, cough). An equally important symptom is pain on the affected side of the chest and in the epigastrium. However, pain is not more common than in 36% of cases. In addition, patients have signs of cardiovascular disorders (cardiac arrhythmias) and gastric dyspepsia (nausea, vomiting). The latter is more common in patients in whom the hernial contents are represented by the stomach [6].

To diagnose diaphragmatic hernia in the first stage, an X-ray examination is performed. However, this method has low sensitivity and specificity and may detect the migration of organs into the chest in no more than 46% of cases [6, 9]. Nevertheless, there are studies in which it is possible to establish the fact of the presence of a hernia in 81% of cases [10]. The best results of pathology verification are guaranteed by MSCT. Signs detected by this method with a high probability (70–100%) indicate the presence of diaphragmatic hernia [6, 10].

In the stage of strangulation of the hernial contents, clinical signs are associated with acute violation of the gastrointestinal tract and blood supply to the deployed organs, which is manifested by severe pain in the epigastrium and chest, vomiting, delayed discharge of stool and gases. Additionally, gastric and intestinal obstruction often complicated by perforation followed by the development of pleurisy and mediastinitis with lethal outcome [11]. In this case, the optimal diagnostic methods are X-ray and CT, which may detect both hernial contents and signs of intestinal obstruction [12]. In complex cases (regardless of the stage of the disease) endoscopic diagnostic methods acquire a significant role: thoraco- and laparoscopy [13].

In the acute period after an injury and in the stage of strangulation of a hernia, the treatment tactics are clearly defined and aimed to exclude life-threatening conditions, and then to restore the integrity of the diaphragm: depending on the size of the defect, it is sutured or plastic with synthetic materials. In the stage of distant manifestations or nonmanifest hernia of the diaphragm, the choice of optimal surgical tactics is ambiguous. In our clinical case, the standard operation to restore the natural topographic and anatomical position of organs and plastics of the diaphragm defect was inadequate for this patient. In the postoperative period, increased IAP was created, which caused a relapse of the underlying disease.

It is quite difficult to establish the cause of this complication. But we suggest that the increase in IAP is associated with modeling of the anterior abdominal wall. Moreover, the severity of morphological changes depends, on the one hand, on the duration of the hernia and the volume of displaced organs, and on the other hand, on the age of the patient at the time of damage to the diaphragm. After injury in childhood, organs migrated to the pleural cavity due to the pressure gradient between the anatomical regions, as a result of which the volume of the abdominal cavity decreases. Accordingly, during the growth and development of the body, the walls of the abdominal cavity adapt to the changed topographic and anatomical conditions. Moreover, an attempt to restore the natural position of organs leads to an increase in IAP and the development of ACS.

However, when analyzing a large amount of foreign literature in the *Medline* and *Embase* databases, no convincing evidence in favor of this hypothesis was found. We managed to find only 2 publications in which the growth of IAP was noted. In a study by *T. de Nadai et al*. [14] 4 clinical cases were analyzed, while the age of the patients upon injury and the duration of the disease were 33 and 4 years, 17 and 8 years, 26 and 6 years, 19 and 5 years, respectively. The development of intraperitoneal hypertension in the postoperative period was observed in the first 3 patients, which is associated with a large volume of hernial contents and the difficulty of performing reconstructive surgery.

In another publication, *A. Pakula et a* . [15] demonstrate an increase in IAP in a patient with a 25-year history of hernias, when a diaphragm damage was received at the age of 12 years. In this case, the cause of the development of the complication is fully consistent with our hypothesis. However, in a study by *S. Singh et al.* [8], despite the duration of the disease (50 years), the age at which the diaphragm ruptured (3 years), and the gigantic volume of migrating organs — the development of a pathological condition after the operation was not revealed.

The increase in IAP and the development of ACS occurs not only after the elimination of traumatic hernia of the diaphragm, these processes are also associated with other etiological factors. Somewhat more often, such a complication occurs after delayed treatment of some congenital diaphragm hernias, in particular, Bochdalek hernias [16, 17].

Regardless of the causative factor, the pathophysiological features and clinical manifestations of increased IAP are identical in all patients and depend on the degree of hypertension. According to the classification of *J.M. Burch et al.* [18] distinguish 4 degrees of IAP increase: 1st degree —12-15 mm Hg, 2nd degree — 15-20 mm Hg, 3rd degree — 20-25 mm Hg , 4th degree — more than 25 mm Hg. In this case, ACS corresponds to a persistent increase in IAP with the manifestation of organ failure. The development of a pathological condition is accompanied by damage to the urinary, cardiovascular, respiratory and nervous systems. However, the most common symptoms are an increase in the abdomen, muscle tension in the anterior abdominal wall, oligoanuria, and respiratory disorders. In the postoperative period, it is possible to diagnose this condition by measuring the pressure inside the bladder, stomach and, less commonly, the inferior vena cava [19]. However, at the final stages of operations, it is often possible to establish the fact of increasing IAP. In this case, the main signs will be the impossibility of closing the laparotomy wound or suturing the defect in the diaphragm without tissue tension [15].

The treatment of patients with these complications may be either conservative or surgical, the conservative one is advisable to use only with a slight increase in IAP [19]. Currently, with the 1st and 2nd degrees of IAP increase without the manifestations of multiple organ failure, methods of nasointestinal intubation, adequate mechanical ventilation, and infusion therapy with crystalloids are used. In addition, positive results were obtained by the introduction of muscle relaxants [14].

With the 3rd and 4th degrees, as well as in cases of the development of ACS, it is necessary to resort to surgical methods of treatment. For small or complicated hernias, the optimal approach is to reduce IAP by decompressive laparotomy. It is believed that after the subsidence of inflammatory phenomena and a decrease in the severity of edema, the volume of organs will decrease and, accordingly, conditions will be created for closing the wounds of the abdominal wall [19]. However, in some cases, this method does not allow to achieve adequate treatment results. *A. Pakula et al.* [15] present a clinical example of a patient with a traumatic rupture of the diaphragm and a hernia performed by the stomach, pancreas, omentum, large and small intestine. The large size and lifetime of the hernia made it impossible to close the laparotomy wound with our own tissues, so the surgeons performed reconstruction of the anterior abdominal wall by strengthening the muscles with a polypropylene synthetic prosthesis.

In our clinical case, we also resorted to reconstructive surgery, while we used the method of V.I. Belokonev [20]. The essence of this technique is to dissect the anterior laminae of the rectus sheaths along the Spigelian line, turn them inward and staple together. Synthetic material is placed on the aponeurosis of the anterior abdominal wall fixing it to the lateral and medial leaflets of the aponeurosis. The use of this method of plasty of the anterior abdominal wall allows to increase the volume of the abdominal cavity and eliminate the risk of increasing IAP and the development of relapse of the underlying disease.

CONCLUSION

Giant post-traumatic diaphragmatic hernias are a rare, but at the same time, natural stage of development of damage to the diaphragm. Due to the lack of clinical symptoms of chronic diaphragmatic hernia and the non-specificity of diagnostic signs, this disease remains unrecognized for a long time. Given the occurrence of a hernia in childhood and a long history of the disease, a complex of pathological changes in the abdominal wall occurs. This leads to the need to perform complex reconstructive operations, which essence is to increase the volume of the abdominal cavity and create normal IAP in it with the reverse movement of the fallen organs. The simple formula that we described can be used to calculate the area of synthetic material both when performing operations for post-traumatic diaphragmatic hernias, and with giant ventral hernias. The given clinical example confirms our opinion.

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