MODERN PRINCIPLES IN SURGERY FOR INJURIES AND DISEASES OF THE SPINE

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ABSTRACT	This article describes the current trends concerning diagnostics and treatment of spinal trauma as well as tumors and diseases of vertebral column and spinal cord. The assessment of computer tomography and magnetic resonance imaging capabilities to reveal various abnormalities of vertebral column and spinal cord is given. The clinical cases of the minimally invasive, endoscopic and percutaneous technologies for treatment of various spinal abnormalities are presented.
Keywords:	trauma, diseases, spine, diagnostics, minimally invasive technologies, surgical treatment.

CT — computed tomography
MRI — magnetic resonance imaging
SCT — spiral computed tomography

Injuries and diseases of the spine and spinal cord are the large social, medical and economic problem. In 1997 — 2012, the number of patients with spinal cord injury increased by 3.5 times in Moscow, and severity of the injury increased as well. Thus, patients with associated injuries of the spine and spinal cord make up 50—60%, while in the 60s of the last century there were no more than 25—28% of such patients. The number of patients with degenerative diseases of the spine, hospitalized in neurosurgical departments of hospitals of the Department of Healthcare in Moscow during the same period increased by 3 times. The similar trend is observed in all countries all over the world [1—3].

There has been a qualitative breakthrough in spine surgery over the past 20 years — modern sophisticated diagnostic technology, microsurgical technique and tools replaced uninformative survey methods, general surgical techniques and instruments and the new minimally invasive surgeries have been developed and introduced [1, 4, 5].

Modern development of surgical techniques, including the development of new systems of fixation of the spine and the new instruments (retractors, flexible illuminator applied into the wound, the use of navigation and intraoperative CT and 3*D* radiography, combining features of the microscope and endoscope in one device — exoscope *«VITOM»*, creation of robotic assistants and so on.), led to the widespread adoption of minimally invasive techniques in spinal surgery. At the present stage, operations on the spine and spinal cord result not only in disability reduction, but also improve the life quality in both the late and early postoperative period, prolong the active life, especially of senile patients [4, 6—10] .

New technologies in spine surgery lead to the emergence of a new methodology and new ideology.

Currently, there are several lines of the modern surgery of spine and spinal cord development: 1) percutaneous methods of fixation and/or stabilization of the vertebrae; 2) minimally invasive access and microsurgical techniques; 3) introduction of endoscopic technologies and navigation, endovasal technology; 4) combination of various surgical techniques [8, 11, 12].

Using high-precision technology surgery involves the use of high-precision methods of diagnosis. X-ray spiral computed tomography (SCT) is the method of choice in the diagnosis of bone lesions and condition of the spine bones. Magnetic resonance imaging (MRI) of the spine has improved the quality of diagnosis of the spine and spinal cord injuries and diseases due to the visualization of soft tissue structures — the spinal cord, discs, ligaments, joint capsule, muscles, and myelographic mode of MRI allowed to eliminate the practice of invasive diagnostic method — myelograpy. For the diagnosis of concomitant vascular lesions or their involvement in the pathological process, MR and CT angiography is used, as well as Doppler ultrasound. Implementation of electrophysiological diagnostic methods along with neuroimaging techniques has allowed not only to verify the slightest damage to the spine and spinal cord on the new level, but also to study the processes occurring in the spine and spinal cord at different times after injury or onset of the disease as well as to monitor the healing process and evaluate its effectiveness [13—16].

These research methods can not only detect all the structural damage to the spine and spinal cord, but also help plan operations, perform it (combined with neuronavigation) and monitor the quality of its conduction (Fig. 1).

Surgery of spinal injuries is based on three main pillars: 1) the need for timely and complete decompression of neural and vascular structures of the spinal canal; 2) full restoration of the vertebral axis in three-dimensional space; 3) effective bone fusion using modern implant technology.

Understanding the pathogenesis of the disease, new data on the biomechanics of the spine and the simultaneous development of medical technology made it possible to create modern implants for spine surgery (Fig. 2). Their performance can be judged by the fact that patients become active within the first hours after surgery for the injury or disease of the spine and spinal cord, and in the absence of damage to the spinal cord they even begin to walk.

New methods of surgical treatment for injuries and diseases of the spine have been developed at the Sklifosovsky Research Institute for Emergency Medicine since 2000. Modern methods of fusion and fixation of the vertebrae (transpedicle screw and laminar hook systems, titanium plates, cannulated screws) have been introduced in the short term. The methods of diagnosis and treatment of patients with fractures of the vertebrae of the neck, multilevel spinal injuries, and new methods of minimally invasive transpedicular decompression of the spinal canal using the original instrument have been also developed. Given the specificity of patients admitted to the Institute, in 2000–2008 there had been the development of diagnosis and treatment for the most severe category of patients — with associated spinal trauma and complications in patients with a spinal cord injury as well as the development of rational algorithm for their prevention and treatment [7, 13, 17, 18].

Since 2005, the Institute has implemented minimally invasive endoscopic procedures on the anterior parts of the vertebral column (Fig. 3). The first operations were carried out in conjunction with thoracic surgery. This allowed not only to reduce the duration of the operation by 2 times and blood loss by 2—4 times, but operating aggression as well.

The use of endovasal technology allows not only to diagnose different vascular impairements of the spinal cord — cavernous angioma, arteriovenous malformations, and treat it by intravascular embolization but also helps in surgery of the spine and spinal cord tumors. Embolization of blood vessels feeding the tumor reduces pain and significantly reduces blood loss during the surgical treatment. A number of patients previously inoperable due to the high risk of fatal intraoperative blood loss and the use of preoperative embolization of tumor vessels allowed to perform open surgery and save the life of a patient (Fig. 4).

Over the past 10 years, minimally invasive techniques in spinal surgery — percutaneous surgery (percutaneous vertebroplasty, kyphoplasty and vertebral stents in their pathological vertebral compression fractures (Fig. 5), puncture hydrodiscectomy etc.), percutaneous transpedicular stabilization of the vertebrae (injuries and diseases of the spine) and endoscopic techniques (Fig. 6, 7) have been widely used at the Institute.

One of the new trends in spine surgery is a combination of endoscopic and navigation technologies performed with an aid of 3*D* modeling of the vertebral column immediately on the operating table. This makes accurate positioning of the implant in the wound possible through relatively small incisions of soft tissues as well as verification of the spinal cord decompression and prevention of its damage (Fig. 8).

The department implemented operations on all parts of the spine. Application of new retractors, microsurgical instruments, microscope, navigation equipment, modern implants and surgical techniques has reduced the duration of operation by 2—3 times, blood loss by 2—4 times, the length of stay by 2—5 times, improved cosmetic effect in access areas and ultimately improved the quality of patients life. Spinal surgery has largely become routine, being performed in many hospitals of the country.

Terms of hospital stay after surgery for spinal injuries decreased by 3—6 times. Eighty percents of patients avoided disability after surgery for uncomplicated spinal injury and 60% of them returned to their previous work. In complicated spinal injury the mortality during the first year reduced by 5—7 times, but there is still high mortality rate in injuries of the cervical spinal cord, going from 50—60% in the 90s of the last century down to 12—15% at present.

Currently, the Institute has been working on the study of multilevel spinal injuries and penetrating injuries of the vertebral column. The background for the use of cellular technology in spinal cord injury is being created.

The use of a complex of modern technologies in degenerative diseases of the spine has made it possible to operate the sick elderly patients, activate them within the first day after surgery, reduce the length of stay by 2—3 times and significantly improve functional outcome, quality and duration of life.

As a result of active research and practical work for the last 12 years, the Institute has become one of the leading institutions in the Russian Federation for the treatment of patients with injuries and diseases of the spine and spinal cord. In 2000—2012, 1,402 patients with spinal cord injuries, spinal cord and its subsequences underwent 1,610 surgeries at the Institute. During the same period 1,126 operations for diseases of the spine and spinal cord were performed.

The staff annually conducts master classes in endoscopic surgery of injuries and diseases of the spine and the use of hemostatic agents in neurosurgery. Along with a detailed lecture course surgeons learn how to work with endoscopic instruments on models and laboratory animals (swine), watch demonstration operations. The book has been released to help learners [19].

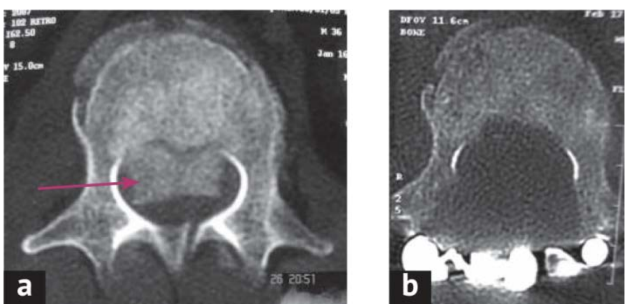

Fig. 1. Computed tomography of L_{II} vertebra in the axial projection: *a* - before surgery, *b* - after surgery. Laminectomy was performed, bone fragments (indicated by an arrow) of the spinal canal were completely removed

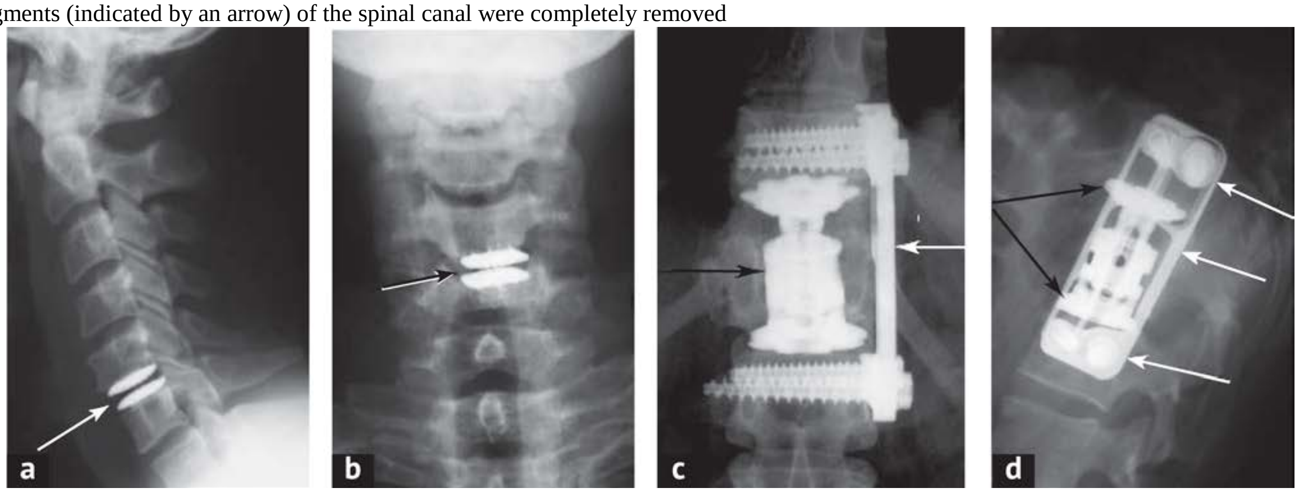

Fig. 2. Radiography images of patients after spinal surgery using modern implants: *a* – lateral view *b* – front view of the cervical spondylograms after discectomy of the $C_{V\text{-}VI}$ herniated disc and installation of the artificial disc (arrow); c – front view and *d* - lateral view radiography images of the spine after partial spondylectomy of Th_{XII} fraction during and stabilization of the spine with the use of prosthetic vertebral body (black arrows) and a titanium plate (white arrows) with endoscopic assistance

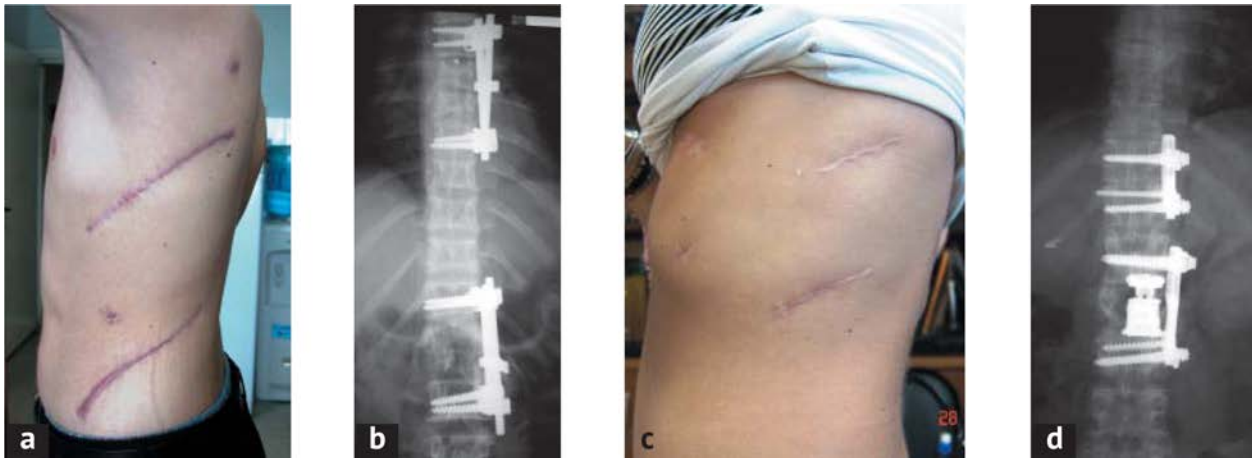

Fig. 3. Type of skin scarring and spondylograms after surgery for multilevel spinal injury: *a* - in typical open surgery, *b* - frontal radiography image of the thoracic spine in the same patient after surgery using the front titanium fixators; *c* - type of skin scarring at the same operation with the use of minimally invasive techniques and videoendoscopic assistance; *d* - frontal radiography image of the same patient after surgery

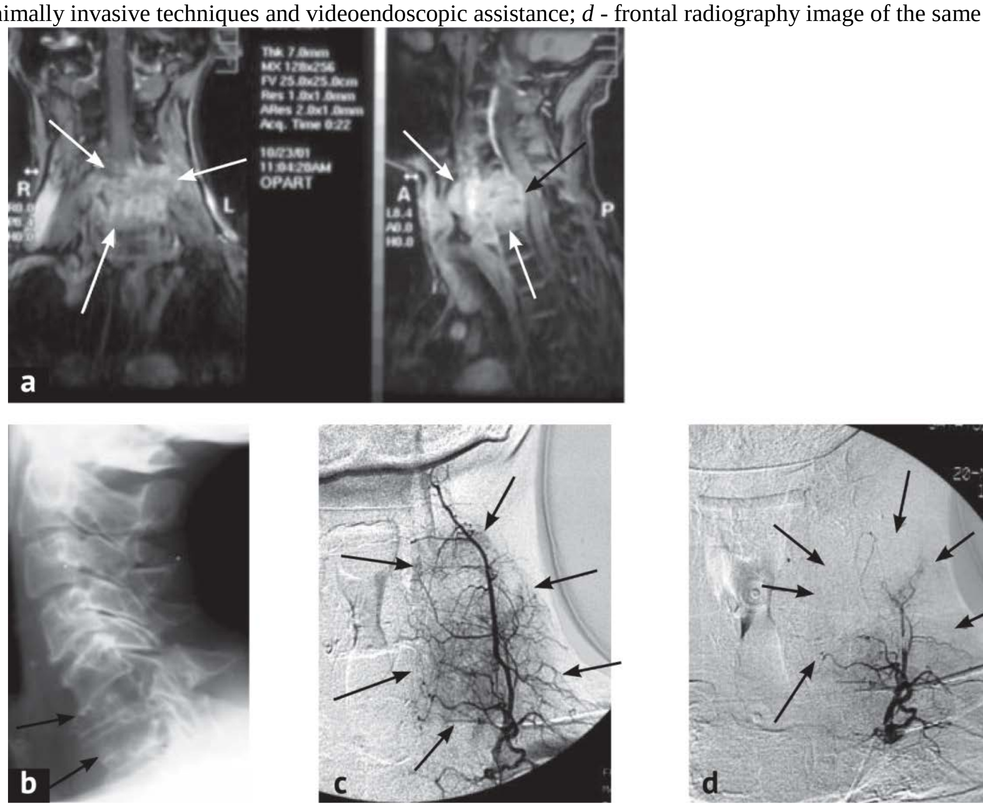

Fig. 4. Radiological examination data of a patient K. with a tumor at the level of $C_{VI\text{-}VII}$ vertebrae: *a* - data of magnetic resonance imaging - white arrows indicate the tumor, the dark arrow indicates compression of the spinal cord tumor, *b* - lateral neck spondylograms - arrows indicate the destruction of the C_{VI} and C_{VII} bodies with the tumor; c - angiogram of the left thyrocervical trunk, which shows abnormal vascular network in the tumor stroma (arrows); *d* - angiogram of the same vessel after embolization - arrows indicate significant reduction of blood flow to the tumor

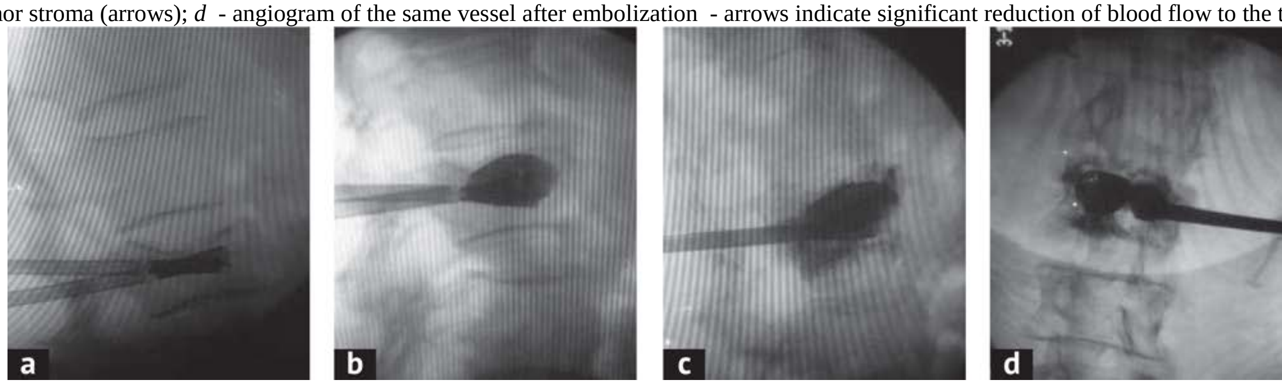

Fig. 5. Intraoperative images of stenting stages of L_{II} with compression fracture under image intensifier monitoring: *a* - introduction of stents into the vertebral body, and *b* - stent expansion with balloons and reposition of the vertebral upper end plate; c - the introduction of cement into the lumen of the stent; lateral view and *d* – front view

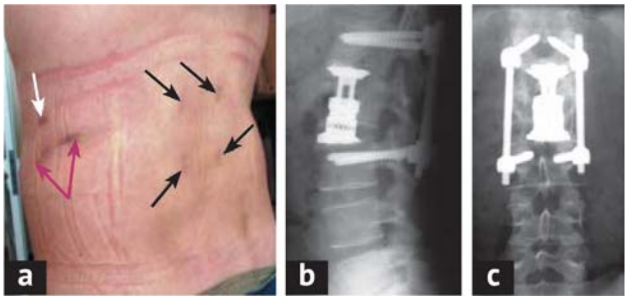

Fig. 6. Minimally invasive surgery for uncomplicated compression fracture of the vertebrae L_{II}: *a* - skin incisions after percutaneous transpedicular fixation (1.5 cm each, black arrows) and after mini-lumbotomy (6 cm, red double arrow) and one hole for the endoscope (1.5 cm, white arrow), *b* - lateral and c – front view radiography images of the patient after posterior transpedicular fusion of L_{II} -L_{III} and anterior fusion of the vertebral body with the telescopic prosthesis

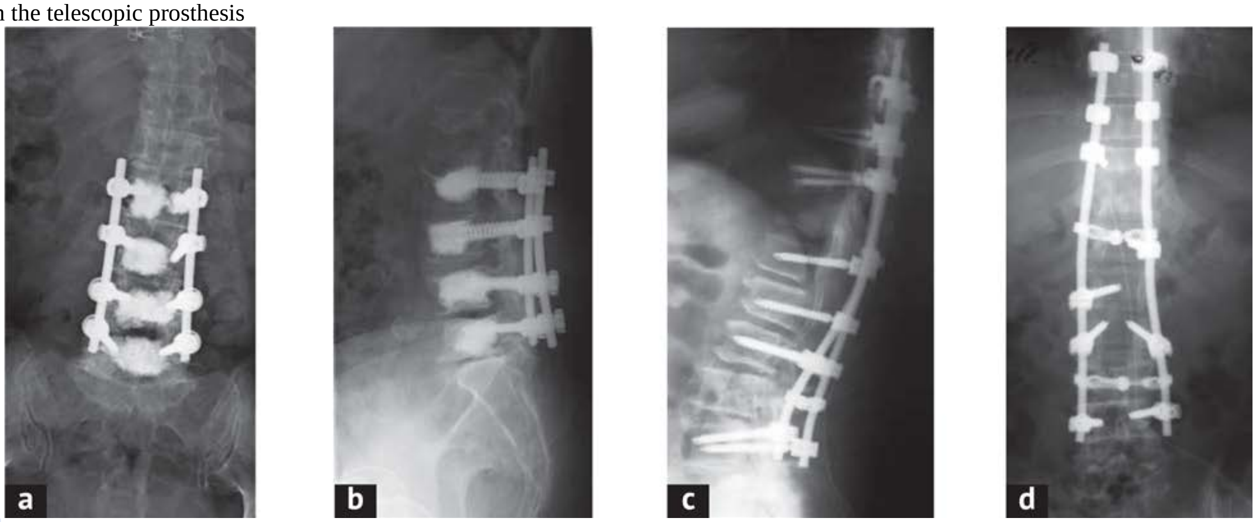

Fig. 7. Spondylograms of patients operated for degenerative spinal spondylarthrosis and polyfactor multilevel spinal canal stenosis at the lumbar level: *a* - front and *b* - lateral view radiography images of the lumbar spine, the patient with severe osteoporosis - transpedicular fixation of $L_{II-III-IV-V}$ supplemented with vertebroplasty for greater rigidity of the system and prevention of its migration; c - lateral and *d* – front view radiography images of patients with transpedicular hook fixation - $Th_{IX-X-XI}$ - L_I -L_{II} -L_{III} -L_V at the contiguous multifactor spinal canal stenosis and compression fractures of Th_{XII} due to osteoporosis

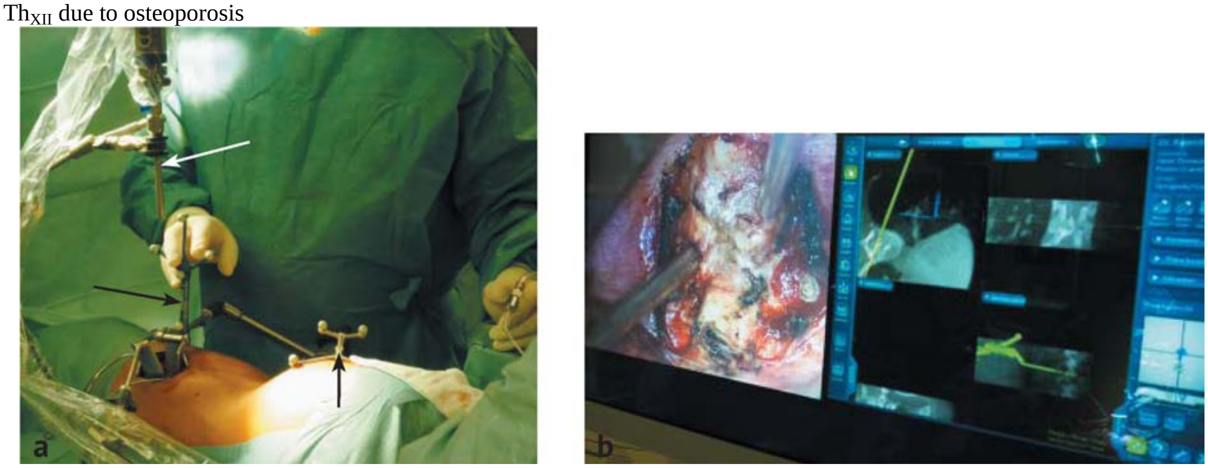

Fig. 8. Intraoperative navigation and endoscopic techniques during transthoracic removal of the disc herniation at the level of $Th_{X-XI:}$; *a* - photo of intraoperative verification of removal completeness of herniated disc using the navigation pointer in the hands of the surgeon (black arrow); white arrow - eksoskope *«VITOM»;* retractors introduced into the wound for minimally invasive surgery, fixed to the operating table and replacing hands of an assistant, *b* - intraoperative photo of an image on the monitor - left view through the endoscope, on the right - the position of the tool in the surgical wound in relation to the spine and the spinal cord in real time

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