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Osteoporotic Vertebral Fractures and Minimally Invasive Percutaneous Approach

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Abstract

Osteoporotic vertebral fractures and related surgical approach are more frequent due to increased average life. In most cases these fractures are atraumatic or associated with a minimal trauma but high-energy trauma are increasing in patients with osteoporotic vertebrae. In addition to the conservative treatment, several surgical procedures are available. Minimally invasive percutaneous approach is a good option for the treatment of osteoporotic vertebral fractures; it is a rapidly developing field that has the potential to decrease surgical morbidity and improve recovery compared to traditional spinal approaches.

Introduction

Epidemiology

Osteoporosis is a systemic skeletal disease marked by a low bone mass and a microarchitectural deterioration of bone tissue, leading to increased fragility and tendency to fractures, especially hip, spine and wrist. The number of fragility fractures in Italy was calculated as follows: 91.494 hip fractures, 61.009 clinical vertebral fractures, 57.401 humeral fragility fractures, and 94.045 forearm/wrist fragility fractures [1]. The incidence of fragility fractures in Italy is very high, and osteoporosis is the leading cause of morbidity in the Italian population. The hospitalization rates of 27.6% for clinical vertebral fractures was observed [2].

The estimated female osteoporosis prevalence women is approximately 15% for the group aged 50-59 years, 25% between 60-69 years, 40% between 70-79 years and even above 50% for age over 80 years. Between 80% and 90% of vertebral fractures in the over 65 years people are caused by osteoporosis, but only one a third are clinically manifest [3,4].

Over 30% of patients affected by osteoporosis vertebral fractures (OVF) needs of surgical treatment and 12% presents complications requiring an invasive surgical approach. In most cases these are pathologic fractures, occurring spontaneously or associated with a minimal trauma [5].

Today, there are more and more dynamic and active "elderly-fit". Vertebral fractures that occurs in these patients could be also specifically traumatic vertebral fractures.

These are not "pathologic fracture", but only vertebral fracture that occur in a not physiological bone. This aspect must be considered influencing any surgical treatment.

Biomechanic

Vertebral body is formed by cancellous bone tissue biomechanically characterized by high bone turnover (80%), lower calcified volume (20%). Therefore, this tissue withstands to the dynamic stresses, deforming itself without breaking.

Degenerative disc disease and senile neuromotor and neurosensory decay, are associated with a spine kyphosis progression resulting in a gravitational axis anterior translation and progressive posterior ligaments distraction and an anterior column compression.

In case of osteoporosis, the trabecular thinning results in a vertebral body strength reduction. In relation to the gravitational force, the fracture of the body induces an height soma reduction and spine kyphosis progression, especially at the level of the anterior spinal column [6,7]. The more involved vertebrae are T7 and T8, in the middle thoracic column and T12 and L1 in the thoracolumbar transition where is realized a great flexion. The thoracolumbar hinge is most subjected to stress being an area of different convex curves inversion. The kyphotic curve progression and gravitational axis forward displacement lead to an increase in flexion, causing new fratture. In fact the risk of another vertebral fracture increases 5 fold after the first event ('domino-effect').

These conditions, must be considered in case of open approach, especially in identifying the level of merger and the location and surgery instrumentation, considering the increased fixation failure risk [8].

Treatment options

The necessity of an algorithm for the treatment of painful osteoporotic fractures is based on the lack of consensus regarding proper surgical indications, timing, application and effectiveness of the percutaneous vertebral body augmentation techniques and the usefulness and indications for open surgery [9]. Although vertebroplasty (VP) and kyphoplasty (KP) are currently diffused, their role is still controversial, especially if compared to conservative treatment [10]. A review of the current literature reports mild and

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transient symptoms in the first month of conservative care. Vertebral body augmentation techniques should be done within 3 months from fracture to promote a good outcome [11]. Instead the vertebral body augmentation could be performed within few days from trauma to encourage a good restoration of vertebral height [12].

One month is the minimum waiting period before considering surgery due to fracture natural history and the higher risk of cement leakage at the first month [13]. VP should be considered for persistent painful fractures with less than 30% of body high reduction, if the conservative treatment failed. KP should be considered for vertebral body collapse equal or higher than 30% within the third month; in particular evidence of edema by MRI, especially with the use of short tau inversion recovery (STIR) sequences, suggests "acute" structural deformity, which can then be corrected by kyphoplasty [14]. This can best be managed when surgery is done within 9 months with the onset of symptoms. There are different systems and devices available for PVAP, with similar characteristics, although they are different for many features : Spine Jack® [15] is a new device for mechanical kyphoplasty. It is a titanium implant designed to restore vertebral height through a distraction effect via bilateral transpedicular minimally invasive approach, the device is inserted into the vertebral body (from T10 to L5) and gradually expanded like a little jack. The distraction exerted by the device allows fracture reduction that occurs by ligamentotaxis on the anterior longitudinal ligament. The presence of two symmetrical devices into the vertebral body also allows a homogeneous spreading of polymethylmethacrylate (PMMA). Spine Jack® has the advantage to restore, according to the "fracture freshness", the vertebral height and the normal spine biomechanic and stability. The restoration of normal spine biomechanics results in an interruption of the domino effect and in a reduction of the risk of new vertebral fractures [16].

Only PMMA administration could be used for VP, allowing vertebral body reinforcement without body height direct restore. KP provides a partial correction of vertebra body height through an "expandable balloon". KP is a more biomechanically valid process. This technique provides for the stabilization of the fracture after reduction. In addition, the creation of an intrasomatic cavity filled with PMMA reduces the risk of cement leakage [17]. Although the majority of PMMA leakages are asymptomatic, adverse effects of VP include localized bleeding, infection, mediastinitis, pain, neurological symptoms (neuropathic pain and paraplegia) and pulmonary embolism following injected material leakage [18].

At the end, open decompression and stabilization techniques are necessary for the treatment of unstable fractures and/or in patients presenting neurological impairment.

Minimally invasive percutaneous approach

When the conservative treatment is not possible and open posterior fusion could represent an overtreatment, minimally invasive percutaneous approach is a good alternative. Minimally invasive techniques have been developed for intertransverse process, posterior lumbar interbody, and transforaminal lumbar interbody fusions [19]. A minimally invasive approach allows a tissue-sparing surgery, providing a blood loss saving and postoperative pain relief [20]. Patients affected by osteoporotic vertebral fractures and candidates for surgery, are suffering from multiple and simultaneous pathologies and are subjected to a multidrug medical therapy. Therefore, where possible, it should be advisable to use a minimally invasive percutaneous screw fixation, although it is necessary an accurate patient selection, in order to avoid needless and dangerous surgical time extension.

This technique involves, through mini-incisions, insertion of pedicle screws with two external tubes and a targeting system. It possible to insert a connection bar, synthesizing the upper and lower vertebrae. Minimally invasive approach is indicated born for vertebral fractures stabilization in polytrauma and patients with immediate need for mobilization. In addition, minimally invasive techniques may be associated with narcotic independence compared with open procedure [21].

This technique shows great advantages: quickly functional recovery, blood loss and postoperative pain reduction. Percutaneous posterior stabilization, used as internal fixation system, should be reserved only to stable vertebral fractures [22] . It is worth to mention that in patients with severe compression fractures with neurological damage, percutaneous fixation of the upper and lower spaces, it must be complemented with a laminectomy to treat spinal cord compression [23]. Today, minimally invasive percutaneous vertebral augmentation with intravertebral polyethylene mesh sac is a new system used in the minimally invasive biologic vertebral reconstruction procedures [24]. It consists of a polyethylene mesh sac, introduced into the vertebral body and filled with morcelized bone allograft. Bone graft is able to create a hyperdense pack, reducing the fracture and restoring vertebral height. Osteoconductive and osteoinductive properties allow a biologic vertebral reconstruction. The adjacent vertebrae should be more protected by a construct with a similar elasticity and physical characteristics of the morcelized bone. In fact the use of bone tissue (autologous/homologous) is still considered the "gold standard" in spinal instrumentation surgical techniques in order to facilitate spinal arthrodesis formation. Autologous bone has the greatest osteogenic potential, but its availability is limited and its use may be associated with painful long-term complications. The use of homologous bone is an important option in case of bulk or structural graft. Bone graft augmentation offers fracture reduction and trabecular stabilization. Long-term findings suggest that bone graft augmentation in osteoporotic patients yields a stable yet less rigid segment, which may reduce the risk of adjacent level fracture. For younger people, the potential now exists for biologic fracture repair. The limitations of the autologous bone substitutes, make it necessary to search for alternatives. Till date, the synthetic bone substitutes represent a partial solution, because they provide some bone mechanical properties such as osteoinductivity and osteoconductivity, but this features remain largely dependent on the presence of vital periosteum and bone [25].

Screw fixation

Biomechanically, the pedicle provides the strongest screw fixation in healthy bone, but in osteoporotic vertebra, trabecular and cortical pedicular bone can be reduced by up to 50% [26]. The instrumentation of osteoporotic spine, especially in posterior stabilization, results in failure in 12% of cases, due to conventional pedicle screw loosening or pull-out [27,28], together with a poor rigidity of the bone-screw contact. A correction failure or nonunion could make surgical revision necessary. Therefore different screw designs and screw augmentation methods should be available [29]. Various methods were developed to increase the screw fixation strength in case of bone deficiency: in 2002 et Sandén al [30] noted that HA coating of pedicle screws resulted in improved fixation of the screws with a reduced risk of loosening.

Perforated screw with vertebroplasty augmentation, solid screw with vertebroplasty augmentation and solid screw with balloon kyphoplasty augmentation are actually used. Alternatively, it is possible to combine sublaminar hooks, wires, conical screws, iliac screws or expandable screws [31], but with higher strength and higher risk [32]. Brantley et al. [33] suggested that there is an interaction between increase in diameter and the increase in length. Polly et al. [34] reported that increasing the length of the screw alone or increasing the diameter of the screw less than 2 mm do not improve screw stability. Screw insertion depth plays a significant role. Screws implanted deeper than 50% into the vertebral body or bicortical screws perforating anterior vertebral cortex, enhance the bone anchorage [35]. However, bicortical fixation was avoided because of the anterior leakage risk. Cement augmentation is regarded as an efficient system to enhance screw strength in osteoporotic bones, transferring the bio-mechanical load anteriorly from the pedicle to the vertebral body . The higher strength of screw fixation can be obtained with the larger amount of injected cement. There could be potential problems, as risk of cement leakage and a difficulty of screw removing. Cook et al. [36] reported that PMMA injection through the expanded screw increased the pullout strength by 250% when compared with the non-cemented expandable screw. In both the techniques, cement is injected prior to screw insertion. Researchers designed an expandable pedicle screw (EPS) able to improve screw stability without harming pedicle, avoiding the risk of vertebral pedicle fracture, vascular and visceral injuries caused by larger or longer screw. Many biomechanical studies have demonstrated that pedicle screw fixation is highly correlated with BMD. Mechanical load influences bone tissue structure according to Wolff's law [37]. As a result, the bone tissue surrounding the expandable portions of the EPS has an high bone density. The expansion of the EPS should also improve fixation strength by allowing greater bone contact, without an increase in pedicle insertion diameter or screw length. EPS enhances screw fixation strength like the traditional method of PMMA screw augmentation [38]. In conclusion, the expandable pedicle screw is an effective, safe and easy method and is indicated in osteoporosis screw stability augmentation.

Conclusion

OVF and related surgical approach are more frequent due to increased average life. The osteoporotic vertebral fractures occur spontaneously or after trauma.

Therefore, knowledge of the different treatments, allows to perform a specific patient care. Conservative treatment is no longer the only solution. Now, many surgical techniques are used (from percutaneous to open combined approaches), allowing a more rapid functional recovery and a biomechanically stable correction. Given the particular characteristics of the osteoporotic spine and patient comorbidity, the treatment must be done according to "early total care", "tissue sparing surgery" and "damage control orthopedic surgery". Supporting this, minimally invasive spine surgery is a rapidly developing field that has the potential to decrease surgical morbidity and improve recovery compared to traditional spinal approaches. Today, nanotechnology could offer vast potential for massive improvement in the field of orthopedic; further studies on the extensive toxicity and safety risks of nanotechnology are necessary before utilizing for the treatment of osteoporotic vertebral fractures [39].

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