90 Percutaneous Spine Applications

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Introduction
Nowadays, technical possibilities allow to significant improvements in spine surgery, minimally invasive and percutaneous interventions are becoming increasingly popular. In percutaneous interventions, scar tissue, soft tissue damage, blood loss, postoperative pain, narcotic use and hospitalization time are less. However, this method has higher risk for neurovascular injury (because of working in narrow area) and also may result in inadequate decompression.

Cervical Percutaneous Interventions

Percutaneous intervention in the cervical spine can be examined under the following headings;

1- Cervical posterior percutaneous interventions
- a) Percutaneous cervical lateral mass and the pedicle screw fixation (of rod systems)
- b) Percutaneous transfacet screw fixation
- c) Percutaneous C2-pedicle (pars) screw fixation in Hangman fractures
- d) Percutaneous posterior atlantoaxial transarticular screw fixation

2- Cervical anterior percutaneous interventions
- a) Percutaneous anterior atlantoaxial transarticular screw fixation
- b) Percutaneous anterior transodontoid screw fixation

1- Cervical Posterior Percutaneous Interventions
In degenerative, tumoral and traumatic situations, cervical lateral mass and/or pedicle screw fixation techniques are widely used for stabilization (56,58,89). The long segment anterior cervical fusion surgery results with high pseudoarthrosis rate (3). Therefore, addition to these interventions posterior lateral mass and/or the pedicle screw fixation is required. Thus, the biomechanical strength of the system will increase and fusion rates will rise.

Minimally invasive and percutaneous interventions are becoming increasingly popular.

Lateral mass screw and rod system is developed by Roy-Camille. Magerl, Anderson, Ann and the Fehlings have modified this technique. Lateral mass screws have risk for vertebral artery (VA) and neural injury. Abumi used cervical pedicle screw stabilization technique for 13 patients with lower cervical spine trauma in 1994 and since the application, this method has been used quite widely. Pedicle screws permit three column fixation and restored the posterior tension band. However, both pedicle and lateral mass screwing cause to neck pain due to muscle dissection (3,49,88,89).

Recently, percutaneous fixation techniques are widely used. Percutaneous cervical lateral mass and transfacet screwing or percutaneous pedicle screwing (for Hangman fracture) and percutaneous posterior or anterior atlantoaxial transarticular screwing (for atlantoaxial instability) methods are also have been used.

a) Percutaneous cervical lateral mass and the pedicle screwing (of rod systems)
Open technique usually requires a wide skin incision and muscle dissection. However, percutaneous lateral mass and pedicle screw fixation can be applied through the tube. However, this method permits only two or three level fixation (88). In addition, rod placement through a tubular retractor causes a long paramedian skin incision and muscle dissection. As a result rod systems can not be considered as a real percutaneous fixation technique.

Percutaneous method permits only two or three level fixation.

Surgical Technique: The patient lies in the prone position on a radiolucent table. Fluoroscopic imaging is used during the procedure. Through the skin, K wire is placed straight to lateral mass. Screw direction should be parallel to the facet joint in the sagittal plane. The entry point is in the middle of the lateral mass (Figure 1a,b).

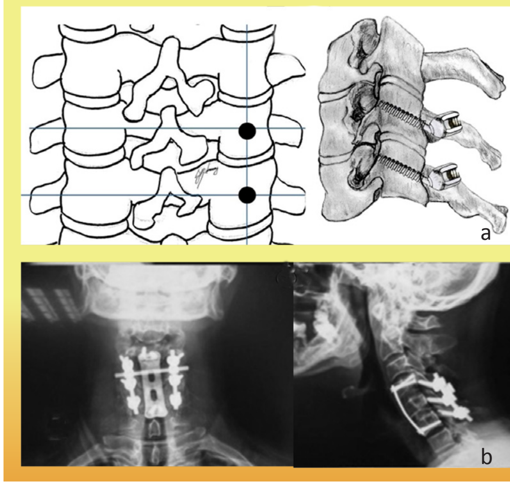

Figure 1

a) In cervical lateral mass screwing, screw entry point and trace of screw are seen in the coronal and sagittal planes in schematized picture. **b)** Posterior lateral mass screwing of a patient is seen on plain radiographs (Yusuf Kurtuluş Duransoy's archive).

Rod systems can not be considered as a real percutaneous fixation technique.

On screw entry point, 1,5-2cm skin incision is made and telescopic tubular dilators are placed. Lateral mass surface is cauterized with monopolar cautery through the wide tube, muscles and soft tissues are removed with a pituitary rongeur. After facet joint is curetted, cancellous autograft bone taken from iliac crest, is placed for fusion. One mm medial side from the midpoint of the lateral mass is marked as entry point. After entered K-wire is advanced parallel to facet joints with an angle of 20 degrees laterally. Then a hole is opened at 14mm depth and a polyaxial screw with 3.5mm in diameter and appropriate length is placed. Screw is similarly placed to adjacent lateral mass and rod is placed from bottom screw to upper screw inside a tubular retractor. During the rod placement, the tube retractor gently lifted up so this maneuver is facilitated the placement of rod to screw head (88).

Risk of transfacet screw stripping is less than lateral mass screwing.

b) Percutaneous transfacet screw fixation
Transfacet screwing has been defined by Takayasu et al. (79) in 2003 and this technique can be used for lower cervical spine fixation. The purpose is to immobilize the facet joints and to compress the facet joint surfaces. The main feature of this technique is no rod requirement and can be applied percutaneously. Percutaneous transfacet screw fixation is an alternative to cervical lateral mass fixation. Neurovascular injury risk is less and has lower screw profile. In addition, muscle dissection in percutaneous method is less so postoperative axial pain will be less (3,56,58,79,99).

In a biomechanical study Klekamp et al. reported that risk of transfacet screw stripping is less than lateral mass screwing (99). DalCanto et al.(16) reported that transfacet screwing and lateral mass screwing have similar biomechanical forces on two segments fixation. Miyanji et al. (58) also reported similar biomechanical results.

Different transfacet screw placement techniques have been described in literature. In Takayasu.79 technique, screw entry point is at the midpoint of 1/3 upper of the lateral mass. Screw direction is 60-80 degrees anteriorly in sagittal plane and 0 degrees laterally in coronal plane straight to the nerve root and VA and passes from four cortex (Figure 2A).

Although this technique seems safer, VA injury can be seen if longer screw is used. In a cadaveric study DalCanto et al. (16) placed the screw (entering point was 2mm caudal of the mid-point of lateral mass) with 40 degrees anteriorly in sagittal plane and 20 degrees laterally in coronal plane straight to caudally (Figure 2B).

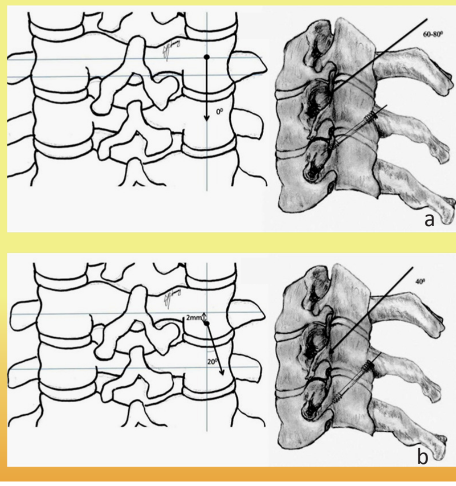

Figure 2

Screw entry point and trace of screw for cervical transfaset screwing **a)** Takayasu (79) technique and **b)** Dalcanto (16) technique.

DalCanto and Takayasu are two different facet screw tecnique.

Similar to DalCanto technique, Klekamp et al. screwed on (with entering point was 1mm medial and 1-2mm caudal of the mid-point of lateral mass) with 40 degrees anteriorly in sagittal plane and 20 degrees laterally in coronal plane straight to caudally (99). Miyamoto et al. (57) modified the transfacet screwing technique and they drilled three cortex instead of four and they had no neurovascular injuries during this process. Miyanji et al. (58) used midpoint of the lateral mass as entry point and placed the screw with 90 degrees to facet joints in sagittal plane and 5 degrees laterally in coronal plane straight to caudally. In 20 cervical spine cadavers Liu et al. (49) studied 160 transfacet screwing to determine the safety of transfacet screws. These authors used 1mm medial of midpoint of the lateral mass as entry point and screwed with 37 degrees anterior angulation in sagittal plane and 16 degrees lateral angulation in coronal plane straight to caudally and they did not determine any artery or nerve damage.

Hangman fracture were classified by Effendi then by Levine and Edwards.

Surgical Technique: The patient is lie in the prone position on a radiolucent table under general or local anesthesia. In order to screwing with appropriate angle, cervical neutral position is preferred. Under fluoroscopy, anteroposterior (A-P) and lateral images are obtained. A guide tube is placed to the entry point, then Kirschner (K) wire is placed and advanced in the appropriate direction. Then drilled with cannulated drill through K-wire. During fluoroscopy appropriate cannulated compression screw is placed over the K-wire. After obtaining the desired compression on facet joints K-wire is removed. In the same way screwing is done on the opposite side and this segment is stabilized.

C2 pedicle screw compresses bone fragments to each other, allows osteosynthesis and protect the motion segments.

c) Percutaneous C2 pedicle (pars) screw fixation in Hangman fractures

Hangman (hanged man) fracture is known as traumatic spondylolisthesis of the axis (15,65,81,93). Effendi (22) has classified hangman fractures in 1981, Levine and Edwards have modified in 1985 (15,65,81). According to Levine and Edwards classification: Type 1: There is no angulation between C2-C3 and displacement is less than 3mm. Type 2: Angulation is 11 degrees or more and displacement is more than 3.5mm .Type 2A has angulation more than 11 degrees without displacement. However, in type 3 there is severe angulation, displacement and single or bilateral facet dislocation (15). In Type 1 conservative treatment, in Type 2 and 3 anterior or posterior surgical interventions are required. While there is debate about the ideal treatment method, C2 pedicle screwing (transpedicle osteosynthesis) is used as an effective treatment method. This method compresses bone fragments to each other, allows osteosynthesis and protect the motion segments (15,65,93,97). However, anatomical variations of neurovascular structures surrounding pedicle makes this technique difficult (64,81,93,97) also in the presence of ligamentous damage or traumatic disc herniation this technique is not used alone (15,81,93).

C2 pedicle screw fixation is firstly defined by in 1964 by Laconte et al., and then was applied by Saillant and Bleyni. Later, many applications have been used (15,65,81,93,97). Dalbayrak et al. (15) reported radiological and clinical improvement with pars screws in 4 unstable hangman fracture patients. Tian et al. (81) applied C2 pedicle screws in 14 unstable hangman fracture patients with three-dimensional fluoroscopy-guided navigation and reported that it is a safe method. Rajasekaran et al. (65) treated 20 type 2 hangman fractures patients with pars screws and reported that 18 of 20 had fusion and no neurologic deficits in all patients.

Recently, parallel to three-dimensional fluoroscopy and navigation systems development, percutaneous pedicle screw fixation has begun (75,93,97). Sugimoto et al. (75) successfully treated a 69 years old patient who had politrauma and hangman fracture with percutaneous C2 pedicle screw using three-dimensional fluoroscopy and navigation. Wu YS et al. (93) treated 10 patients who had unstable hangman fracture with percutaneous C2 pedicle screws using fluoroscopy-guided and they reported that they had no perioperative complication. Yoshida et al. (97) treated a patient effectively with percutaneous C2 pars screwing method who had unstable hangman fracture.

Percutaneous method has some advantages such as shorter operative time, less bleeding, lower infection risk, less muscle damage and quicker healing.

In percutaneous technique, variations of the neurovascular anatomy of the pedicle and surrounding tissue should be detailed preoperatively. Before applying this technique, anatomy of this region should be known. Nevertheless, percutaneous method is technically safer and easier. Also percutaneous method has some advantages such as shorter operative time, less bleeding, lower infection risk, less muscle damage and quicker healing (93,97).

Surgical Technique: After routine general anesthesia and intubation, in order to receive A-P fluoroscopic image of the atlantoaxial structure a radiolucent bite block was placed in the patient's mouth. Patient is lie in prone position on radiolucent with slightly cervical extention. One cm skin incision is made on 5cm lateral and 4cm caudal to C2 spinous process and a guide tube is placed on C2 lamina. K-wire is placed from this guide under fluoroscopy and navigation control. Then K-wire is sent with hand drill through C2 isthmus until it reachs to anterior cortex of the vertebral body. Over a guide wire a way is opened with cannulated drill and cannulated compression screw with 3.5mm diameter and appropriate length is placed and tightened to increase the compression effect (Figure 3A,B).

Magerl and Seemann was defined the posterior atlantoaxial transarticular screw fixation (PTS).

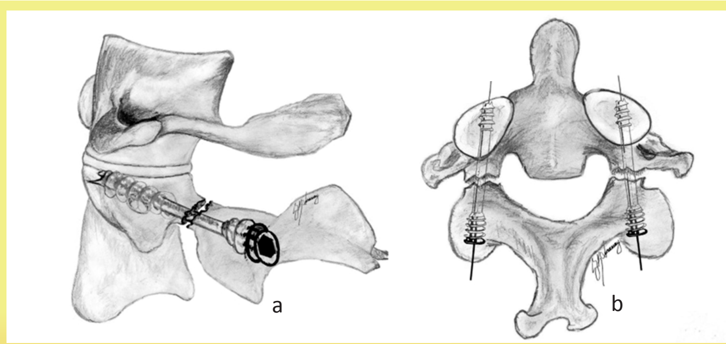

Figure 3

The trace of C2 pars screws in the treatment of Hangman fractures are seen a) Sagittal, b) Coronal plane in schematized picture.

d) Percutaneous posterior atlantoaxial transarticular screw fixation

Posterior wiring methods such as Brooks and Gallie which were used in the past for atlantoaxial fusion are biomechanically weak and fusion rates are low. Despite lateral mass and pedicle screw fixation techniques are biomechanically stronger, these methods have high rates of VA injury and causes to severe tissue damages. Transoral C1-C2 plaque application is also biomechanically stronger however this method has disadvantages such as increased risk of infection, narrowing of surgical field and delaying of mucosal healing (42,66).

In 1987, Magerl and Seemann was defined the posterior atlantoaxial transarticular screw fixation (PTS). This method has become a standard surgical technique for atlantoaxial subluxation with high fusion rate (95-100%). It is strong as biomechanically (42,60,66,69,71,86,94). However, this technique is very difficult or even impossible in severe thoracic kyphosis. Prone position can be disadvantage for patients who have low respiratory capacity. In addition, complications such as spinal cord injury, neurovascular injury, screw malposition or screw breakage have been reported (42,66). Neo et al. (60) treated 43 patients who had atlantoxial instability with open methods PTS by using a special tool and reported that it was a safe method.

Percutaneous PTS has been described by McGuire and Harkey (69,94) ElSaghir et al. (23) applied percutaneous PTS in 2005 (ElSaghir) and treated 57 patients who had atlantoaxial instability due to rheumatoid arthritis by using special tool and screw driver. Kaminski et al. (38) applied percutaneous PTS in 47 patients who had traumatic atlantoaxial instability and they reported shorter operation time, less bleeding, low complication rate and high fusion rate (100%) in this technique. Blauth et al. (8) compared open and percutaneous PTS and have reported that there was no difference in the fusion rate. In a study with 17 patients Schmidt et al. (69) compared percutaneous technique and open technique. They concluded that percutaneous technique has shorter operation time and less bleeding.

PTV has become a standard surgical technique for at-lantoaxial subluxation with high fusion rate (95-100%).

Percutaneous technique has advantages such as short operative time and less bleeding (8,38,69,94) However, transarticular screw fixation is technically difficult procedure and includes VA injury risk (60,94).

Entry point is 3mm superior and 2mm lateral of inferior medial corner of C2 inferior facet and passes from C2 isthmus (20) (Figure 4A,B).

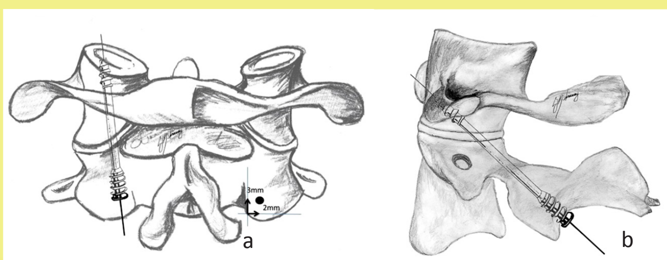

Figure 4

The screw entry point and trace for posterior transarticular screwing are seen **a)** Coronal, **b)** Sagittal plane in schematized picture.

In order to give the cranial angle to screw, a skin incision is made in upper thoracic region.

Surgical Technique: The patient is lie on the table in prone position under general anesthesia. After fluoroscopic control, vertical skin incision is made on C1-C2 segment. In addition, in order to give the cranial angle to screw, a skin incision is made in upper thoracic region which let passing of the trocar (Figure 5).

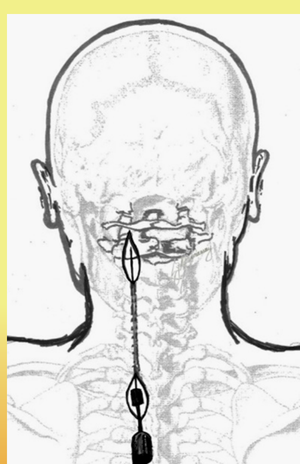

Figure 5

Patient position and localization of the skin incision for posterior transarticular screwing are seen in schematized picture.

According to the preferred technique, K-wire cross atlantoaxial joint and placed to C1 lateral mass. After preparation of screw hole with cannulated drill, screw with 3.5mm diameter and appropriate length is placed over the K-wire.

2- Cervical anterior percutaneous interventions

a) Percutaneous anterior atlantoaxial transarticular screw fixation
Anterior transarticular screw fixation (ATS) has advantages such as providing strong stabilization with a single surgical approach and avoid from prone position. Therefore, it seems as an alternative method for atlantoaxial instability treatment (2,66). This method causes less soft tissue damage than posterior muscle dissection (42,66,86). In extreme lateral position, VA injury damage and in extreme upward orientation occipito-cervical fusion may cause (2). However, the risk of VA injury is less in ATS than PTS (94).

The risk of VA injury is less in ATS than PTS.

Barbour has identified C1-C2 transarticular lateral approach for the first time in 1971. However, this approach has not received the attention in the literature. Du Toit have modified and used this technique in odontoid fractures in 1976 and reported good results. Lesoin has modified this approach again in 1987, and reported good results (42). Lu and Ebraheim, (50) have applied screw entry point, which was described by Lesoin on 15 cadavers under fluoroscopy control. They identified that screw direction should be 5-25 degrees laterally and 10-25 degrees posterior in the coronal and sagittal plane respectively to prevent neurovascular injury. Apostolides et al. (6) have described triple screw technique using bilateral ATS and anterior odontoid screw fixation in a 85 year old patient who had unstable atlas-axis fracture. Vaccaro et al. (83) have obtained fusion by C1-C2 anterior transarticular screw fixation in nonunion type 2 odontoid fracture. Reindl et al. (66) were performed triple anterior screw fixation successfully in a patient who had unstable odontoid fracture with atlantoaxial dislocation. Agrillo et al. (2) have used transodontoid screw fixation and bilateral ATS (triple anterior screw fixation) in a 92 years old patient who had combined atlas and axis fracture and authors reported this technique as easy and safe.

Kim et al. showed that there was no significant difference as biomechanically between ATS and PTS. (42) Sen et al. (71) have similar biomechanical results. Koller et al. (42) studied on 42 healthy adult's computed tomography and have defined ATS' specifications. Xu et al. (94) measured the 120 percutaneous screws way (for ATS and PTS) in 60 patients on three-dimensional computed tomography and have calculated risk of the VA injury. VA injury is less in percutaneous ATS than percutaneous PTS.

There is no significant difference as biomechanically between ATS and PTS.

Dean et al.(dean) have implemented triple anterior screw fixation successfully in a patient who had combined type 2 odontoid fracture with atlas fracture and emphasized that this was a safe method. Wu AM et al. (92) have applied combined percutaneous anterior odontoid screw fixation and percutaneous bilateral ATS to 7 patients who had C1-C2 fractures in 2012 without complication (including VA, nerve or soft tissue injury) and reported fusion in all patients. Wang et al. (86) have applied endoscopically assisted ATS to 7 patients who had traumatic atlantoaxial unstability without major perioperative complications and reported fusion in all patients.

In percutaneous method, less soft tissue dissection, less bleeding, less postoperative pain and lower infection risk was reported (86,92).

In ATS, the recommended screw entry point on A-P is, 5-10mm lateral from midpoint of the lower edge of C2 vertebral corpus (42,86,92,94) Lu (50), Reindl (66) and Sen (71) have described the screw entry point as medial of the atlantoaxial joints which was 5mm lateral from the bottom of the odontoid. In the coronal plane screw way should be 20-30, 20, 5-25, 20, 25 and 30 degree laterally according to Xu (94) and Wu AM (92), Dean (18), Lu (50), Sen (71), Riendl (66), Wang (86) respectively straight to cranial direction (Figure 6).

In the sagittal plane screw tracing passes through the middle of the C1-C2 joint and screw way should be 20-28, 10-25, 15, 25, 30 degree posterior according to, Xu (94) and Wu AM (92), Lu (50), Dean (18), Wang (86), and Sen (71) respectively (Figure 7A,B, Figure 8).

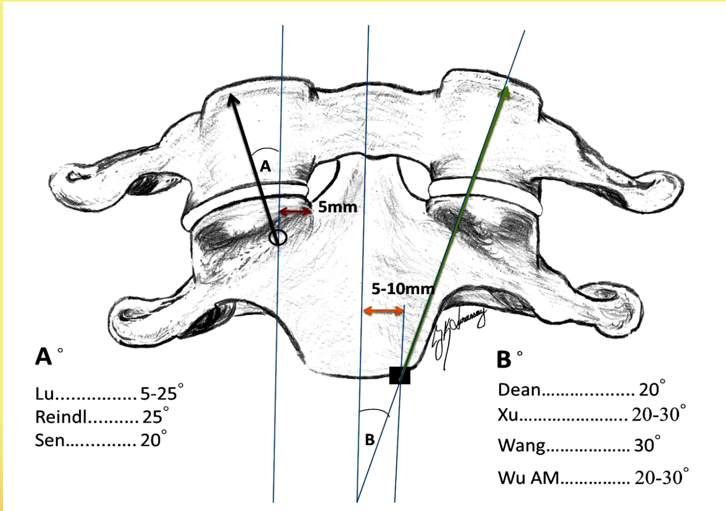

Figure 6

The screw entry point and trace of screw for anterior transarticular screwing are seen in the coronal plane in schematized picture.

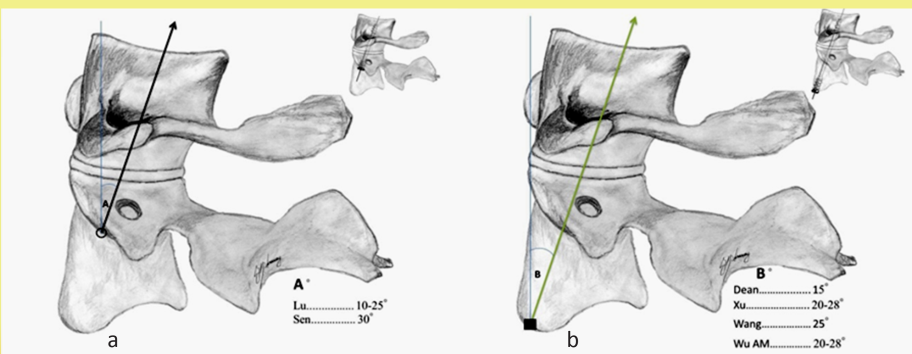

Figure 7

The screw entry point and trace of screw for anterior transarticular screwing are seen in the sagittal plane schematically.

There are different techniques according to the entry point.

Figure 8

Plain radiographs of a patient with anterior transarticular screwing are seen (Yusuf Kurtuluş Duransoy's archive).

b) Percutaneous anterior transodontoid screw fixation

Odontoid fractures constitute 9-15% of all cervical vertebrae fractures.85 Anderson and

D'Alonzo were divided odontoid fractures into three types. Type II fractures and some type III fractures are unstable an ideal treatment method is transodontoid screw fixation (21) Transodontoid screwing provides direct osteosynthesis of odontoid fractures with 85-100% fusion rates and at the same time allows normal atlantoaxial rotatory motion (13,21,85).

Transodontoid screw fixation has been described in 1982, by Böhler (10) Then, in order to facilitate this process, a number of devices have been used (5,13,20,21,33,41,74,85). Dickman (20) used cannulated screws with K-wires in 1995, Apfelbaum (5) applied odontoid screw through a guide tube system and Hashizume (33) reported first endoscopic odontoid screw fixation in 2003. Duransoy et al. (21) used a new guide tube in traditional anterior cervical approach for anterior odontoid screw fixation. (Figure 9)

Transodontoid screwing provides direct osteosynthesis of odontoid fractures with 85-100% fusion rates.

Figure 9

Cannula guide used by the Duransoy et al. (Yusuf Kurtuluş Duransoy's archive).

Kazan et al. (41) firstly have described percutaneous odontoid screw fixation in cadaveric specimens. Later, Chi, Sucu, Wang have reported percutaneous clinical applications (13,74,85). Chi et al. (13) treated 10 patients with percutaneous transodontoid screw fixation technique and reported that this method was safe and reduce bleeding and postoperative pain. Wang et al. (85) compared traditional open screw fixation and percutaneous odontoid screw fixation and reported shorter operation time and less bleeding in percutaneous method. The same authors stated that, learning time was long in percutaneous method and there was no statistically significant for radiation exposure between two methods. Sucu et al. (74) treated 5 patients who had odontoid fracture with percutaneous odontoid screw fixation by using telescopic tube system and reported that this technique was a safe and effective method.

One cm vertical skin incision at medial site of the right sternocleidomastoid muscle (SCM) on C4-5 level is made.

Anterior Transarticular and Transodontoid Screw Fixation Surgical Technique

The patient is lie in a supine position on a radiolucent table with slightly head extention under general anesthesia. A radiolucent bite block was placed in the patient's mouth and C-arm fluoroscopy is positioned. One cm vertical skin incision at medial site of the right sternocleidomastoid muscle (SCM) on C4-5 level is made. Here, 25-30cc of 0.9% NaCl is injected between the carotid sheath and tracheo-esophageal complex. This process will loose neurovascular tape between the carotid sheath and tracheo-esophageal complex. Platysma and SCM are dissected with a clamp. Guide tube is moved with blunt dissection between medial of the carotid artery and lateral of the trachea and esophagus until it reaches to front of the vertebral corpus. The guide tube is moved up along the vertebral corpus until it reaches to front-lower edge of the C2 vertebral body. If odontoid screw fixation will be done, sharp K-wire is advanced with hand drill through the guide tube from midpoint of C2 front-lower edge to posterior superior end of odontoid tip as traversing the fracture line. A hole is opened by cannulated drill, and compression screw with 3.5mm diameter and appropriate length is sent via the K-wire (Figure 10A,B).

If transarticular screw fixation will be done, cannula is moved to front face of atlantoaxial joint. Soft tissues on the joint surfaces are cleaned with electrocautery and joint space is decorticated with an angle curette (Figure 11).

Figure 10

a) Peroperative fluoroscopy images are showing the trace of K-wires for odontoid screwing (Yusuf Kurtuluş Duransoy's archive). **b)** Plain radiographs of a patient with odontoid screwing are seen (Yusuf Kurtuluş Duransoy's archive).

Figure 11

Peroperative decortication of C1-C2 joint with an angle curette is seen in fluoroscopic image (Yusuf Kurtuluş Duransoy's archive).

Peroperative decortication of C1-C2 joint has to be made.

A small amount of iliac crest cancellous bone graft is placed to front of the joint and joint space.

For left transarticular screw fixation, guide tube is placed to entry point under fluoroscopy according to preferred technique. K-wire is moved by hand drill through the guide tube toward the center of C1 lateral mass in appropriate sagittal and coronal angles.

Then a larger cannula is placed outside of the guide tube, and then the guide tube is removed. Then a screw hole is opened by cannulated drill and a compression screw with 3.5mm diameter and appropriate length is sent via K-wire. After checking the correct placement of the screw K-wire is removed. The same process is applied to right atlantoaxial joint through the left side incision (Figure 12).

Percutaneous Thoracolumbar Interventions

Fusion and stabilization are processes that widely used in treatment of degenerative spine diseases, trauma, tumors, spondylolisthesis, and spinal deformities (14,45,59,61,72,78). Lumbar interbody fusion is a widely accepted method which was first described in 1930 by Capener. Cloward has used anterior lumbar interbody fusion (ALIF) and posterior lumbar intervertebral fusion (PLIF) in treatment of spondylolisthesis in 1953 (4,84). ALIF has some advantages such as prevention of paraspinal muscle injury, protection of posterior spine elements and reducing the neural injury risk. Transforaminal lumbar interbody fusion (TLIF) is a well-known technique which describe in 1998 by Harms et al. (14,72,84) In this technique, there is no injury risk for the anterior abdominal structures, vessels, sympathetic nerves, peritoneal and retroperitoneal structures (14). In 2001 Pimenta et al. have identified far lateral interbody fusion which protects both abdominal structures and the posterior osteoligamenteous structures. This technique has advantage such as protection of normal spinal anatomy and less neural injury risk when compared to the other techniques (84). However, many biomechanical studies showed that intervertebral lumbar fusion does not provide solid fixation alone, particularly in extension and axial rotation. Following this process, pseudoarthrosis is observed highly. Therefore, to improve fusion rates additional posterior stabilization is needed (4,44). Pedicle screw is well known and effective in many spinal diseases for stabilization (4,14,45,59,61,72,78). In pedicle screwing technique, to reach screw entry point and in order to give the proper angle to the screws, serious muscle dissection is needed so prolonged postoperative pain is occurred due to denervation of the muscles and facet joint. In addition, operation time is longer, bleeding is more and infection risk is increased. Hospitalization and recovery time is also longer (36,45,59,61,96). For these reasons, percutaneous pedicle screws (PPS) and percutaneous transfacet screwing (PTFS) which are less invasive and have equal activity have been used.

ALIF has some advantages such as prevention of paraspinal muscle injury, protection of posterior spine elements and reducing the neural injury risk.

Foley et al. have identified minimally invasive TLIF (MissTLIF) in 2003. MissTLIF reduces muscle damage, blood loss, postoperative pain, hospitalization time, postoperative narcotic use, and allows to early mobilization. ALIF and axial lumbar interbody fusion (AxiaLIF) are also effective minimally invasive approaches for lumbar fusion. In addition to these minimal invasive methods, PPS and PTFS has been widely used (72).

Intervertebral lumbar fusion does not provide solid fixation alone. Therefore, to improve fusion rates additional posterior stabilization is needed.

Figure 12

Perioperative and postoperative plain radiographs of a patient with triple anterior screwing (Yusuf Kurtuluş Duransoy's archive).

Percutaneous thoracolumbar pedicle screw fixation

Percutaneous pedicle screws (PPS) techniques are becoming more popular with expanding indications (9,43,45,29,78,96). PPS application has a number of advantages compared to other pedicle screw placement techniques. Paravertebral muscle damage, blood loss, postoperative analgesic use, operative time and hospitalization time is less in PPS (9,12,14,28,29,36,44,45,59,96).

However percutaneous system has a limited overview and screwing is more difficult when compare to traditional system. Therefore cannulated screw system was developed. Moreover, nowadays, video navigation system also makes screwing easy (36,61). Nevertheless, a preoperative planning should be done for all the screws (45).

Oh et al.(61) (in a clinical series with 237 spondylolisthesis patients) were administered 558 screws in 126 patients with the classic method and 498 pedicle screws in 111 patients percutaneously. Authors reported that there was no statistically significant for pedicle penetration and penetration severity between two methods. Lowery and Kulkarni applied PPS with fluoroscopy guidance in their 80 patients and have identified that 10 (12,5%) of 80 patients had incorrect screws placement which required revision. On the other hand Wiesner et al. applied 408 pedicle screws with percutaneously to L2-S1 segments and reported that misplacement rate was 6,6%45 Lee SH et al. (44) applied pedicle screws with percutaneously to 73 patients who have low-grade isthmik spondylolisthesis and reported misplacement rate as 4,1% in.

Long learning time is disadvantage of PPS9,96 Despite screw malposition rate was reported from 4,1 to 12,5% in the literature, difficulty of this surgical procedure should be kept in mind and only experienced spine surgeons should be done (45). Mobbs et al. (59) applied 700 pedicle screws percutaneously and reported that only 2 screws had malposition. However, all of the screws were placed by a single experienced surgeon.

Screw malposition rate was reported from 4,1 to 12,5%.

In percutaneous method, more fluoroscopic control is required. Therefore, more radiation is affected (12,45,59,61). However Grass et al. reported that there was no statistically difference for both surgery and radiation time and screw placement accuracy between percutaneous method and traditional methods (45) Lehmann et al.(45) in a study with sheeps reported that, radiation time is longer in the percutaneous group and there was no difference for surgical time between the two groups and noticed that blood loss was less in percutaneous group.

PPS is used as a popular method in thoracolumbar trauma and short-segment fixation and results are quite good in selected patients (9,29,36,43,78). This method is an appropriate method for unstable fractures which does not required open neural decompression. Lee JK et al. (43) have done short-segment pedicle screwing to 32 and 27 of 59 patients who had thoracolumbar burst fracture with percutaneous and open technique respectively and reported that percutaneous group had shorter operative time, less blood loss and less pain. Also authors stated that both groups prevented the kyphosis. Takami et al. (78) applied hydroxyapatite blocks to broken vertebral corpus in 21 patients who had thoracolumbar burst fractures. Authors sent screws to lower and upper vertebrae with percutaneously and then removed the screws five months later. They stated that, they prevented spine angulation and adjacent segment damage and this method allow to early mobilization. As a conclusion they reported this method is a good choice especially in younger patients. Wang J et al. (87) applied short-segment PPS fixation (without fusion) to 26 patients who had unstable burst fracture and they removed the screws in 9-12 months. In follow-up they did not determine adjacent segment disc degeneration. In a retrospective study including 21 patients who had thoracolumbar burst fracture Yang et al. (96) reported that PPS technique is a safe and effective method. These studies show that PPS is a good alternative technique to open techniques. However, this intervention does not include fusion so screws should be removed after fracture healing (96).

PPS is used as a popular method in thoracolumbar trauma and short-segment fixation.

Surgical technique: A vertical skin incision (1-1.5 cm) is made to the lateral of pedicle. A 14 Gauch (G) needle is advanced targeting superolateral edge of pedicle. Then a 20cm length K-wire is advanced through the needle from pedicle to corpus under fluoroscopic control. The needle is removed and pedicle is drilled with cannulated drill through K-wire and cannulated screw is sent. If cannulated screw will not use, normal pedicle screw can be sent after removing of K-wire. Pedicle screw is placed similarly to other vertebra. Rods are placed correctly under fluoroscopy and system is tightened (44,61) (Figure 13,14).

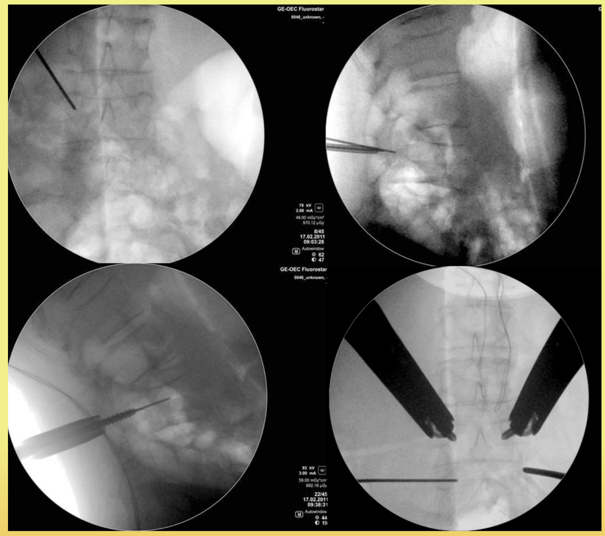

Figure 13

Perioperative fluoroscopic images of percutaneous lumbar pedicle screwing are seen (Erkan Kaptanoglu's archive permission).

A vertical skin incision (1-1.5 cm) is made to the lateral of pedicle. A 14 Gauch (G) needle is advanced targeting superolateral edge of pedicle

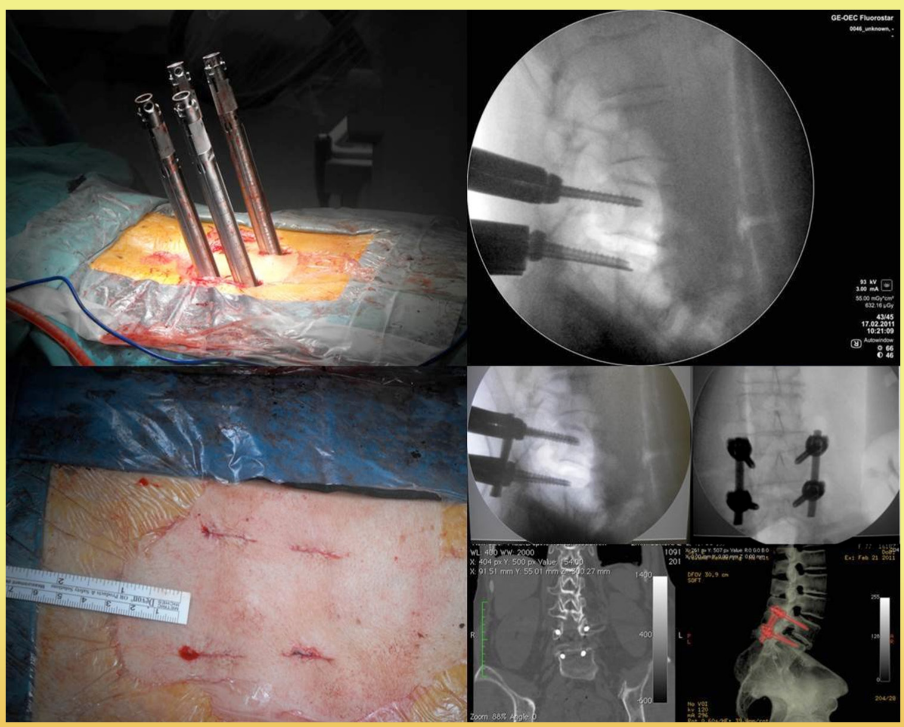

Figure 14

Perioperative and postoperative images of a patient with percutaneous lumbar pedicle screwing (Erkan Kaptanoglu's archive permission).

Percutaneous lumbar transfacet screw fixation

Transfacet screw fixation is a method commonly used after ALIF or in the presence of anterior pseudoarthrosis (4) Transfacet open screw technique was defined by Boucher (11) in 1959. Also in 1984, Magerl was defined the open translaminar facet screwing (4,24,84). Another feature of this technique is screw has low profile. Also screws make facet arthrodesis by compressing the facet joint (84). Biomechanical studies showed that transfacet screwing technique and pedicle screwing have similar degree for stabilization (4,24,84). In clinical studies, it was reported that over 90% fusion was obtained (4,84).

Biomechanical resistance of transfacet pedicle screws to flexion-extension loading is as strong as rod and pedicle screw system (24).

Percutaneous technique can be performed under local anesthesia. Operative time is shorter and creates less muscle damage. In addition, this technique causes to less postoperative pain and less bleeding. CT or fluoroscopy guided PTFS is fast, safe and effective method (4,84).

In a retrospective study, Jang and Lee (35) compared 40 and 44 patients whom applied ALIF plus PPS and ALIF plus PTFS respectively. They reported that there was no difference for fusion rates between two groups. In 2005 Amoretti et al., (4) performed PTFS to 79 patients whom applied ALIF and 28 patients with anterior pseudoarthroses. Authors have reported high fusion rates.

Surgical technique: The patient is lie in prone position. A pillow is placed under abdomen. According to Amoretti screw direction should be perpendicular to facet joints and screw path should be elapsed the middle of facet joint. (4) Under CT-guidance, skin entry point, angle and distance from the midline is marked. Local anesthetic is given subcutaneously. A Chiba needle with 20G diameter and 20cm in length is entered with the specified angle. This needle is used as a guide to place the trocar (13G diameter and 10 cm in length). For translaminar facet screwing, trocar is placed to laminospinous junction on the opposite side of the spinous process of the upper vertebra. A hole is drilled to the opposite lamina. The trocar is passed by crossing the center of the facet joints and is terminated at the base of the lower vertebra transverse process. The same procedure is applied to opposite site with different angle to prevent overlapping of screws4 (Figure 15a, b).

Screw direction should be perpendicular to facet joints and screw path should be elapsed the middle of facet joint.

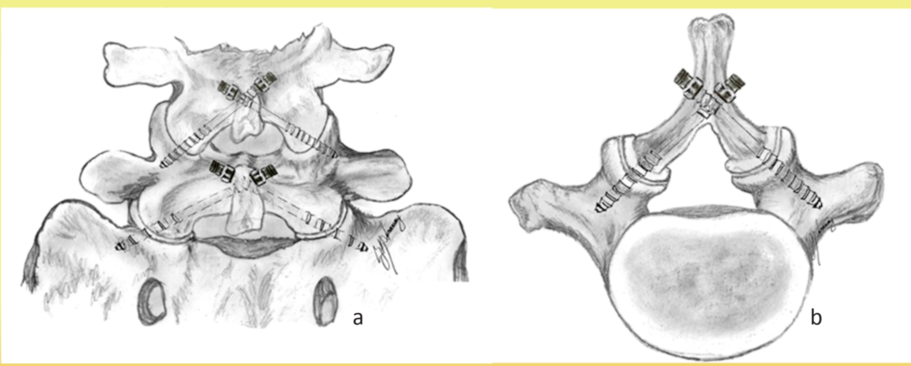

Figure 15

Lumbar laminar transfacet screwing is seen **a)** Coronal, **b)** Axial plane in schematized picture.

Biomechanical studies showed that transfacet screwing technique and pedicle screwing have similar degree for stabilization

For transfacet pedicle screw, trocar is placed to transition region between pars interarticularis of upper vertebra and the inferior articular process. Then trocar is advanced through the same side pedicle by lower vertebra and crossing the center of the facet joints. Cannulated screw in 3.5mm diameter is placed through the K-wires and trocar is removed. The same procedure is also applied to the opposite side (4).

Transfacet screwing can be performed in prone position. Voyadzis et al. (84) defined that, it can also be applied in the lateral direction in patients whom undergoing lateral interbody fusion.

Lateral and extreme lateral interbody fusion is applied in lateral decubitis position. Table is flexed, A-P and lateral fluoroscopic images were obtained. After placing interbody fusion with appropriate techniques, flexion of the table is corrected and transfacet screwing is done in the same position. For this, two upper spinous process from desired disc is determined and 1.5cm vertical skin incision is made. In A-P fluoroscopic image, upper vertebra's lower endplate should be seen as a line (Figure 16).

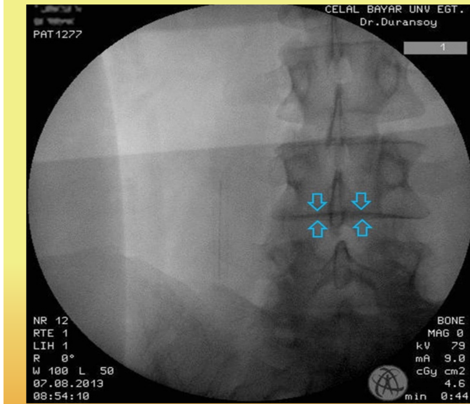

Figure 16

AP fluoroscopic image of lumbar transfacet screwing.

In this fluoroscopic image, entry point should be on the vertical line which combine the medial edges of the pedicle and where intersect the upper vertebra's lower endplate. On lateral fluoroscopic image direction of the Jamshidi needle should be straight to transition point and on A-P image should be straight to inferolateral corner of the pedicle. The needle is positioned with 30 degree anterior in sagittal plane and 15 degree lateral angulation in coronal plane straight to caudally (Figure 17A,B).

Entry point should be on the vertical line which combine the medial edges of the pedicle and where intersect the upper vertebra's lower endplate.

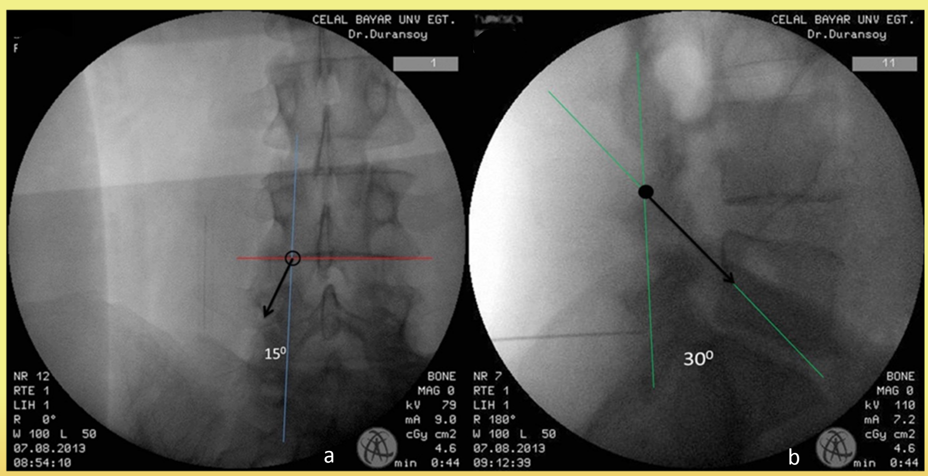

Figure 17

The screw entry point and trace of screw in lumbar transfaset screwing are marked on **a)** AP and **b)** lateral fluoroscopic images.

On lateral fluoroscopic image direction of the Jamshidi needle should be straight to transition point and on A-P image should be straight to inferolateral corner of the pedicle.

Jamshidi needle is fixed with hammer in this position. İnner stylet is removed and the K-wire is advanced with the help of a hand drill. After removing the needle, dilator is placed over the K-wire. The outermost tube is left and others removed. Through the K-wire cannulated drill is advanced and a hole is opened then cannulated compression screw is inserted. K-wire is removed after fluoroscopic control and the same process is applied to the opposite side from the same incision (Figure 18A,B).

Lumbar interspinous devices

Lumbar spinal stenosis is a major cause of disability and chronic pain. Lumbar spinal stenosis is commonly seen in elderly can occurred due to hypertrophy of ligamentum flavum, facet joint degeneration, disc herniation, osteoartrosis, degenerative spondylolisthesis. In lumbar spinal stenosis, back, hip and leg pain are exacerbated by standing and walking (axial loading) and decreasing in flexion position and sitting (39,46,53).

Drug treatment (analgesics and steroid injections, etc.) and physical therapy are generally used as conservative treatment methods. In patients who do not benefit from conservative treatment, laminectomy is the classical surgery method. Laminectomy causes serious muscle dissection and retraction. In addition, there are risks such as dural tears, epidural hematoma, nerve root injury, and blood loss (46,53).

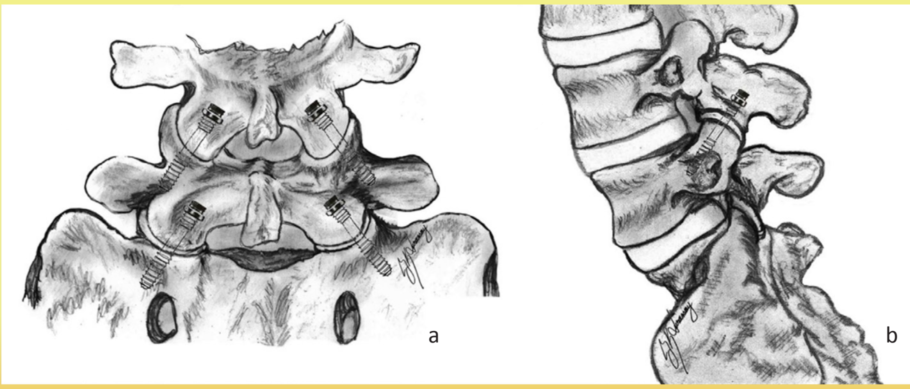

Figure 18

Lumbar transfacet screwing is seen **a)** Coronal **b)** Sagittal plan in schematized picture.

Percutaneous lumbar interspinous device provides dynamic decompression is obtained.

Percutaneous lumbar interspinous device application is an alternative to open surgery laminectomy and laminotomy procedures. There are different types of devices which are manufactured by different companies.

These devices designed to keep spine segment in neutral or slightly flexed poition so pain is reduced. Although interspinous distraction restricts the extension in this segment it allows to flexion, axial rotation and lateral bending. Thus, the dynamic decompression is obtained. In contrast to traditional methods, this technique is minimal invasive with shorter processing time and less complication. Patients can be discharged at the same day because general anesthesia is not required (39,46,53).

Zucherman et al. reported improvement of complaints and neurological deficitis in 75% of patients after 1 year follow up time. Lee J et al. reported similar results. In a study Siddiqui et al. reported 54% and 71% as the improvement rate and satisfaction rate of patients respectively. Kuchta et al. reported improvement in pain scores (2 year continuing pain VAS and ODI scores) (53). Masala et al. (53) reported improvement in pain and disability (duration 6 months). Kantelhardt et al. (39) were found 42% reduction in neurogenic claudication and radicular pain at the end of the first year. As a result, interspinous devices can be a safe and easy treatment method for lumbar spinal stenosis in patients whom can not tolerate surgery.

Interspinous devices can be a safe and easy treatment method for lumbar spinal stenosis in patients whom can not tolerate surgery.

Surgical technique: The patient is lie in prone position. A pillow is placed under abdomen. Intervertebral space is determined by fluoroscopy. Three cm vertical skin incision is made on the right or left side of the midline. After muscle dissection reaches to laminae. Sometimes a small piece of lamina can be removed and appropriate interspinous device is placed to intervertebral space with special instruments. Thus, the required expansion of the spinal canal is obtained and pressure over the neural tissue is reduced. During this process maximum effort should be given to prevent interspinous and supraspinous ligament injury (53,46) (Figure 19A, B).

Percutaneous axial lumbar interbody fusion (AxiaLIF)

Lumbar disc degeneration is common in the elderly and cause of low back pain in adults (98). Symptomatic instability is very common at L5-S1 and L4-5 segments (52). First line therapy includes physical therapy, analgesic use and activity limitation. In the presence of complaints more than 6 months, posterior, anterior and transforaminal interbody fusion (ALIF, PLIF, TLIF) may be required (82,98). Sometimes patients may not be tolerated the open surgery for some reasons such as muscle and ligament dysfunction, corruption of disc annulus, injury risk of visceral and neurovascular structures (52,82,98). For these reasons minimally invasive fusion surgery has been widely used. A small skin incision, less tissue damage, less postoperative pain, less blood loss, shorter hospitalization time are a few advantages for minimally invasive fusion surgery. These methods are less invasive but injury risk of organs are similar to open surgery.

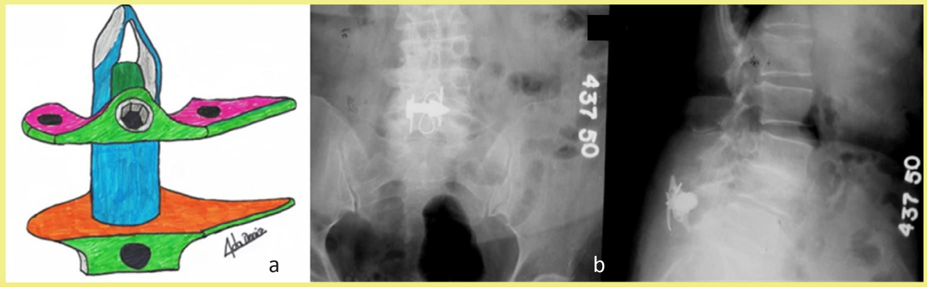

Figure 19

Interspinous device (X-Stop), **a)** Schematized picture and **b)** Plain radiograph image are seen (Yusuf Kurtuluş Duransoy's archive).

AxiaLIF is implemented from as presacral retroperitoneal space where is anatomically safe region (52,54,98). In addition, large blood vessels, neural elements, facet, lamina, dorsal muscle and the anterior ligament of the abdominopelvic cavity are in safe in this method (52). Presacral region is limited with parietal fascia of the sacrum from posterior and with visceral fascia from anterior. This area is filled with organized connective tissue which does not include nerves and vessels. But the middle sacral artery, vein, hypogastric and parasympathetic nerves (originated from S3-S4 in men and S1-S2 in women) are seen in this region (52,98). Therefore, technically there is bleeding risk for sacral vein and sacral artery. However, this structure is removed from the region by blunt dissection so the risk of injury is low. Also risk of neural and vascular injury is low because anatomically S1-S2 junction is a safe area (52).

Lumbar disc degeneration is common in the elderly and cause of low back pain in adults

AxiaLIF is contraindicated in severe scoliosis, spondylolisthesis (grade 3 or 4), tumors, osteoporosis or trauma (98). In addition, this technique has some risks such as pseudoarthrosis, infection, sacral fracture, pelvic hematoma, nerve root irritation and perioperative rectal perforation (54,91). Appropriate patient selection, careful examination of the surgical area in preoperative imaging, preoperative intestine cleaning, surgical technique and perioperative antibiotic prophylaxis reduced the complication risks. Intestine perforation is a rare complication and can be prevented. Gundanna et al. reported rectal perforation risk as 0,6%. Intestine cleaning should be done in previous night. Also placement of a foley catheter in the rectum would be useful for feeling of the rectum borders during blunt dissection (54.98). After the widespread use of the technique, low complication rate and high fusion rates have been reported (98). Zeilstra et al. reported 87,8% of fusion rates without complication (98). Tobler et al. (82) have used AxiaLIF system in 52 patients at L4-5 and L5-S1 levels. They reported 94% fusion rate after 2-year follow-up without serious complication. Bohinski et al. reported 100% of fusion rate.

AxiaLIF is contraindicated in severe scoliosis, spondylolisthesis (grade 3 or 4), tumors, osteoporosis or trauma

As a result AxiaLIF is a safe and effective technique for lumbosacral fusion in symptomatic degenerative disc disease (82,98) and with this technique, adjacent vital structures are at minimal risk (52).

Surgical Technique: After general anesthesia in the prone position, the patient is lie with lower limbs flexed 45 degrees. Anus is isolated and a buffer is placed into anus. Area is cleaned and drape is adhered. On the right or left side of the parakoksigeal notch (20mm caudal) 15mm skin incision is made. Following the injection of local anesthetic fascia is cut. Then, blunt dissection is done with fingers to remove rectum from the sacrum. Guide cannula is inserted and advanced until reach to inferior end plate of the sacrum. During this process, in order to avoid the lateral sacral foramen, fluoroscopy control is required. Cannula is placed to the midline of the anterior cortex of the S1-S2 junction. K-wire is advanced to L5 vertebra corpus through sacrum and L5-S1 disc space. Then a working channel is created by dilatators series. A tunnel is opened by drill from S1 vertebra to L5 vertebra corpus. In this step discectomy is done with specially designed tools, and the endplate is scratching to create fusion surface. Then bone material is placed to L5-S1 disc cavity. AxiaLIF rod is advanced through the sacrum until it entered 0.5-1 cm to L5 vertebra corpus. Advancing screw provides distraction of the disc space, restoration of disc height and opening of the foramina (Figure 20).

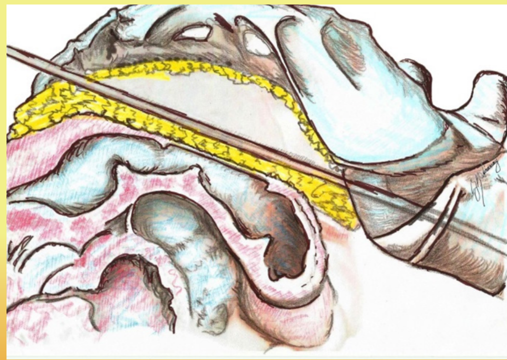

Figure 20

AxiaLIF application is seen in schematized picture.

Percutaneous Spine Biopsy

In treatment of vertebral lesions definitive diagnosis is important. Despite advances in imaging techniques, diagnostic difficulties are still continuing. Tissue samples are often required for definitive diagnosis (30,34,37,40,68,70). This procedure can be made during surgery (open biopsy) or percutaneously (closed biopsy). Open biopsy has a significant complication risks. However, percutaneous biopsy has several advantages such as less tumor spreading risk, shorter hospitalization time, shorter operation time and low morbidity rates. Percutaneous technique allows reaching to regions where impossible with traditional surgery and radiation therapy can be started earlier. Also risks associated with general anesthesia can be avoided. Postoperative wound infection and pathologic fracture risk is less. Also it is a simple and minimally invasive technique (1,25,34,37,40,62,63,68, 73,80,90).

As a result AxiaLIF is a safe and effective technique for lumbosacral fusion in symptomatic degenerative disc disease.

Percutaneous biopsy of the spine is firstly described by Robertson and Ball in 1935 and they made blind biopsy without use of radiologic guidance (7,25,34,48,67). Siffert and Arkin reported radiographic guidance percutaneous biopsy in 1949 (1,7,25,34,67). Adopon used computed tomography (CT) as guidance for percutaneous biopsy in 1981 and reported that it was safe and effective (7,34,67). After that many authors have published their CT-guided percutaneous biopsy series (17,26,48,55,67,68,73).

Different approaches were described (Ashizawa,sucu) as an alternative to classic posterolateral paravertebral approach due to its technical complexity and complications risk (major blood vessels, the risk of injury to the spinal cord and nerve roots) (7,73). Brugieres et al. reported transcostovertebral approach for thoracic spine biopsies in 1990, (73,67) then in 1991, Renfrew et al. (67) reported transpedicle biopsy technique. Sucu et al. described transforaminodiscal approach in 2003 (73).

Postoperative wound infection and pathologic fracture risk is less. Also it is a simple and minimally invasive technique

Indications: Percutaneous biopsy indications for spine lesions;

1. To determine the nature of solitary vertebral lesions (34,62,63),
2. To isolate the causative agent of infectious, osteomyelitis or discitis (17,63,70),
3. To exclude malignancy (metastases or myeloma), in the presence of unstoppable or increased pain with vertebra fractures (34,62,63),
4. To evaluate the tumor recurrence (62),
5. To evaluate the response to spondylodiscitis treatment (17).

Contraindications: The only absolute contraindication for percutaneous spinal biopsy is abnormal-uncorrected bleeding and clotting time (34,62,63). Relative contraindications are suspection for highly vascular lesion and the presence of other lesions (34).

Preparation and planning: Before percutaneous biopsy, anticoagulation should not be given to patients. Anticoagulation should be stop 1-2 weeks prior (40,48) and in infective cases antibiotics should be stop 48 hours prior to the biopsy (17,55,62,70). Also prior to biopsy, coagulation tests (prothrombin time, activated partial thromboplastin time), and platelet counts should be performed (26,40,48,62,63). The patient's vital functions should be monitored during the procedure (48,62) and oral (55) or intravenous sedation can be done (48,62,63).

To avoid possible complications, CT and MRI evaluation of the target region should be considered prior to biopsy (34,62,63,68). Large blood vessels, nerves, peritoneal cavity, spinal canal and healthy tissue compartments should not be on biopsy tracing. In multiple lesions, biopsy should be planned for superficial one. In cervical region, maximum effort should be made to protect trachea, esophagus, carotid artery and internal jugular vein. In thoracic region, pleural space, superior vena cava, thoracic aorta, abdominal aorta and in the lumbar region, the inferior vena cava, renal vessels, nerve roots, and organs such as the kidney should be noted (62). In the presence of suspection for discitis, biopsy should be taken from disc and the adjacent subchondral bone (55,62). All of the material should submit for cytological, histological and microbiological examination (17,55,62,63,70).

There are different types of needle such as Chiba, Osty-cut, Tru-cut, Craig, Ackermann, Temno, Jamshidi and, Harlow-Wood for percutaneous biopsy (1,25,26,34,48,62,67,70,90). Any of these can be used according to the nature of the lesion and the surgeon's preference (34,40,62). Their diameter is between 11G and 22G (62). Thick needles on the one hand provide high accuracy rates, (25,90) on the other hand have high risk for vessels and nerve injury and further spread of malignant tumors (7). Therefore, thickness and length of the chosen needle can be important to receive adequate sampling and to reach the lesion (7,62). For culture or cytology, thin needles are beneficial for aspiration of fluids, soft tissue lesions and disc. While sharp needles can be used to obtain solid samples from bone or soft tissue, sharp and suction needles can be used for cortical destructive bone's lesions biopsy. Trephine needles have serrated cutting edge and are usually required to obtain bone specimens (62).

The only absolute contraindication for percutaneous spinal biopsy is abnormal-uncorrected bleeding and clotting time.

After the procedure puncture site is closed to prevent potential complications. Medication is applied or sedation is continued for a period of time for pain prophylaxis. If pleural was puncture accidentally radiological follow-up will be required for development of pneumothorax (62).

In infective lesions, cytological and microbiological investigations are increase the diagnostic sensitivity of lesions (17,55,62). Blood clots which are obtained from biopsy may contain cells or organisms so these clots therefore should be evaluated (62,80).

Position and Approach: Prone position is preferred for thoracic and lumbosacral spinal lesions biopsy (48,55,62,67). Also in cervical region if pedicle and posterior elements lesions biopsy will be done, patient lies in prone position. Sometimes the patient could be in the lateral decubitus, semi-prone or semi-supine position. This is mean to minimize the movement of the patient and to ensure patient comfort (48,62). Supine position is used in the anterior cervical lesions (31,40,48,62).

Thick needles on the one hand provide high accuracy rates, (25,90) on the other hand have high risk for vessels and nerve injury and further spread of malignant tumors

For posterior cervical thoracic and lumbar vertebrae lesions, posterolateral, paravertebral, transpedicle, transcostovertebral or transforaminodiscal approaches are used (25,48,62,63,67,73). All of these approaches are applied in the prone position. Which approach should be used is depends on the localization of the lesion. If the lesion has located in disc space or to the bottom of the vertebra paravertebral approach should be used (34,48,63). The most common approach used for vertebra corpus is paravertebral approach. However, due to the high risk of complications, some authors do not suggest this approach as a first choice excluding disc biopsy. But in large paravertebral masses and abscesses this approach could be used. Narrow space between large transverse process and the adjacent ribs blockes to reach vertebra corpus in thoracic region (73). Also to reach small lesions which are in posterocentral localization by paravertebral approach is difficult (34,63,67). If the lesion is in the posterior half of the vertebral corpus, or if there is an pedicle involvement transpedicle approach is an effective method (63,34) (Figure 21).

Although transpedicle technique appears to be safe, (67,90) it may be difficult to pierce the shell of cortical bone. Another factor limiting the transpedicle approach is pedicle width. Sucu et al. (73) described the transforaminodiscal approach as a safe alternative method to posterolateral approaches and they reported that in vertebrae's cranial lesions this approach is easily applicable with low complication risk. Garces et al. (26) defined the lateral approach which allows to access the lumbar vertebra corpus, disc space, and paravertebral masses. The patient lies in the lateral decubitus position. In this position abdominal organs are displaced to forward, and this position provides a clear lateral view of the lumbar spine. Advantage of this approach is the needle entry tracing is far from the nerve roots.

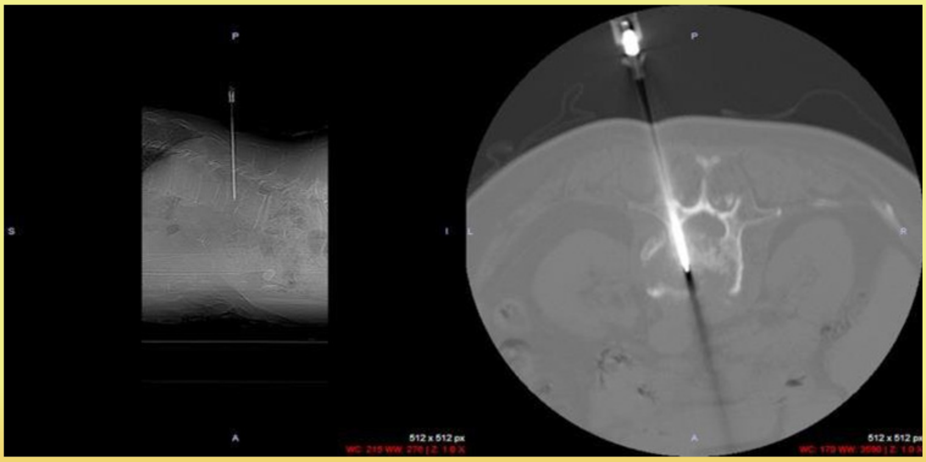

Figure 21

Computed tomography (CT) guided percutaneous spine biopsy by transpedicular approach image is seen (Yusuf Kurtuluş Duransoy's archive).

If the lesion has located in disc space or to the bottom of the vertebra paravertebral approach should be used

For C3-C7 anterior vertebrae lesions, anterolateral approach is preferred in supine position. While biopsy needle is advanced straight to vertebra lesion, carotid sheath (content carotid artery, juguler ven and nerves) is preserved by fingers (31,40,62). Lesions which are located in the upper cervical anterior region, trans-oral route can be used as an anterior approach. In this approach general anesthesia should be applied and infection risk is higher. According to the location of the lesion posterior approach can be used. In particular, at C1 and C2 levels more attention should be given for vertebral artery and dura mater. This process could be applied both in prone and lateral decubitis position. Also lateral approach with retropharyngeal route could be applied for both lower and upper cervical vertebrae (31,40,76).

Radiological Guide: Percutaneous spine biopsy can be applied with different imaging modalities. These include fluoroscopy, (1,7,25,34,37,63,80) CT, (17,26,40,48,55,67,68) ultrasound (US) (30) and magnetic resonance imaging (MRI) (27,47).

If the lesion is in the posterior half of the vertebral corpus, or if there is an pedicle involvement transpedicle approach is an effective method

The imaging method that will be used for guidance of percutaneous biopsy is determined by the the surgeon's personal experience and available technical possibilities (62) CT-guided biopsy is commonly used for the diagnosis of vertebra lesions (26,48,55,67). Ultrasound-guided biopsy is especially used for lesions which are close to the surface, and lesions which are associated with soft-tissue or forming in cortical destruction. Ultrasound-guided biopsy is recommended for the cervical spine lesions. However, in thoracic and thoracolumbar spine, posterior elements limit the process (30) MRI-guided biopsy is used for lesions which are not seen on fluoroscopy and CT (27,47,62).

Although CT scan may seem safer by showing the position of the needle and anatomy in detail, the potentially negative biopsy rates are similar to fluoroscopy. According to Nourbakhsh et al. there is no significant difference for qualification, accuracy and complication rates between the two methods (34). Also CT-guided biopsy is applied in less sterile environment and in longer time (34,55). Fluoroscopy-guided biopsy is done in the real-time and shorter time (34,55,63,70). Also fluoroscopy guided biopsy is applied in operating room so this allows quicker intervention in the presence of a serious complication (7,34). CT-guided biopsy has been reported as a safe and effective method by several authors (17,40,48,67,68).

Diagnostic accuracy rates: The diagnostic accuracy of the biopsy results, may vary depending on the nature and location of the lesion, type of the biopsy needle and experience of the surgeon (62,68,70). The accuracy rates of transpedicle and posterolateral biopsy approaches are equal (62,63). In various studies diagnostic accuracy rates are reported from 68% to 97% (7,30,34,37,48,55,63,68,80). Large needle diameter has high diagnostic rate (25,48,90). Thoracic biopsies have lower diagnostic rates than other levels (62). However Özerdemoğlu et al reported that they got low diagnostic rate in sacral biopsies (70). Rimondi et al. (68) had lower accuracy rate and higher false negative rate in the cervical region and there was no significant difference between other regions. Lis et al. (48) have been reported that they found high accuracy rate in all spine levels and there was no different ratios between all levels. De Lucas et al. (17) made biopsies for infective lesions and have been reported that there was no accuracy difference for the diagnosis of their biopsies in thoracic and lumbar regions. Sucu et al. (73) reported that there was no difference in accuracy rate according to location of lesion. Also they concluded that best diagnostic accuracy rates can be achieved by selecting convenient method. Malignant tumors biopsies have higher accuracy rates than benign tumors and infections (25,62,68). Sclerotic lesions have lower diagnostic accuracy rates and more false-negative rates than osteolytic lesions (48,62). Kamei et al. (37) reported that there was no difference between osteolytic and sclerotic lesions for the diagnostic accuracy rate. Low diagnostic accuracy rate is reported for spondylodiscitis (17,70). Lower rates are obtained in the use of antibiotics prior the procedure (55,70). Michel et al. (55) made biopsy for the diagnosis of spondylodiscitis and they did not use antibiotics prior the procedure. As a result they reported high accuracy rates such as 83% and 91% for microbiological and histological evaluations respectively. According to these authors, the disc space and paravertebral abscesses are sterile regions. Infection agents are usually located to vertebral subchondral region by hematogenous way. Authors stated that, they have higher accuracy rate from subchondral biopsy samples (55).

Fluoroscopy-guided biopsy is done in the real-time and shorter time

Complications: Percutaneous biopsy has risk. However with a careful technique complications are very rare (62,34). Type and possibility of complications depends on, type of the biopsy needle and lesion location (37). In literature, complication rates have been reported from 0% to 10% (7,17,25,26,30,34,48,63). Nerve root injuries, local infections, pneumothorax, vascular injury, paraspinal hematoma, transient paresis, paraplegia, meningitis and death has been reported in the series. Pulmonary, neurological, and infective complications are seen most common. Also complications such as transfusion requiring bleeding, needle breakage, neural injury, spinal cord compression, bleeding of hypervascular lesions (renal cell carcinoma metastasis or hemangioma) may develop (17,25,34,48,62,63). In addition, De Lucas et al. (17) reported a patient with cardiac arrhythmia during the procedure. Pneumothorax is seen from 4-11% in thoracic spine biopsy (62). Along the needle tract, malignant tumor cells and infectious agents can spread (34,62). Sampling from different regions by using single needle tract will reduce this risk (62,63,70).

Malignant tumors biopsies have higher accuracy rates than benign tumors and infections

In conclusion, percutaneous spine biopsy is a simple and repeatable process with acceptable complication rates. In the presence of negative biopsy result, repeating biopsy or open biopsy is required. However, in repeated biopsies' success rate is lower than the initial biopsy. Repeated biopsy may cause delay in treatment so in this cases open biopsy should be considered rather than a needle biopsy. Patient mismatch and difficult localization can cause low diagnostic accuracy rate. In general, false negative rates are low, and if radiological evaluations are done carefully before the procedure, this ratio will be lower (68,73).

Complication rates have been reported from 0% to 10%

Percutaneous drainage of the infection

Spine epidural abscesses have serious morbidity and mortality rates. Abscesses can cause irreversible rapid clinical deterioration. Therefore, early diagnosis and treatment is important (32,51,77,95). Spine epidural abscess is treated with surgical decompression and antibiotics. Patients with normal neurological examination or with mild neurological deficitis are treated with antibiotic treatment. In the presence of progressive deformity, instability, neurological deterioration or antibiotic treatment failure surgical intervention is preferred (19,51,95). In surgical treatment, combined anterior-posterior approach, debridement and fusion are done. Complication rate was approximately 11%. Especially aorta, vena cava and azygos system are under risk. In elderly patients with poor general condition perioperative morbidity is increased (19,95).

Percutaneous interventions are often used for diagnosis (51,95). But rarely percutaneous abscess drainage can be applied for treatment (51). This process can be used in epidural abscess as well as in the intervertebral discitis (32). In addition, this process can be repeated and is minimally invasive. If dura is perforated, meningitis can developed (51,77). However, use of CT as guidance, reduced this risk but this method is contraindicated if abscess is located to anterior (51).

Cwikiel et al, reported drainage of epidural and psoas abscess with antibiotic therapy for 2 weeks in a patient who had psoas and epidural abscess. Walter et al. have identified percutaneous continuous drainage of spinal epidural abscess and irrigation in a 9-month-old infant (51). Tabo et al. (77) were applied percutaneous drainage and irrigation of spinal epidural abscess by epidural needle and catheter in two patients and noted that radicular and back pain were improved in these two patients. Nagata et al. treated 23 patients who had early spondylodiscitis and success rate was 87% with percutaneous drainage. Haaker et al. reported that they treated 16 patients by percutaneous lumbar discectomy who had lumbar discitis (95).

In the presence of negative biopsy result, repeating biopsy or open biopsy is required.

Spine epidural abscess is treated with surgical decompression and antibiotics.

Surgical Technique: This procedure can be performed under general or local anesthesia (32,95). The patient is lie in prone position on a radiolucent table. After determining targeted region under the scope, 8-12 cm lateral from the midline is marked (95). Spinal needle is advanced toward the center of the targeted disc or the abscess. In discitis this process can be applied by transpedicle approach (32). Biopsy samples are taken from the infected area for microbiological and pathological examination. Then infected region is irrigated with saline and permanent drain is left (95).

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