CT-guided sacroiliac screws placement

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Resume

In 2013 the Emergency Department of Policlinic Umberto I of Rome was declared HUB[1], which means a regional reference center for the traumas of the pelvis. The increasing amount of work caused the research of other intervention methods to reduce the occupation time of operating rooms for orthopedic surgery (average time 80 ’).

CT guided percutaneous fixation is described in literature as an accurate and safe method with little incidence of complications in the reduction of posterior pelvic instability.

In this article we describe our experience by reporting the technique used for the placement of cannulated screws in the sacroiliac joint, the image acquisition method, the execution times, the average dose delivered and the outcome.

[1] organizational model of high specialties that refers to the production and distribution of hospital care according to the principle of integrated clinical networks "HUB & SPOKE" which provides for the concentration of the most complex cases, or which requires more complex production systems, in a limited number of centers and the activity is strongly integrated, through functional connections, with that of the peripheral hospital centers (SPOKE).

Purpose: The authors report their early experience in CT-guided sacroiliac joint fixation, unlike how it is normally performed in the operating room with subsequent CT scan. This essay analyses the abundance of benefits that CT offers in pelvic traumatology.

Materials and Methods*:* 19 Patients with B and C fractures according to tile classification (Koo H, 2008) were treated with a variable number of cannulated screws (from 1 to 3) with length between 5 and 10 cm and with diameter between 6,5 and 8 mm. The operations were performed with CT-guiding system, local anaesthesia and percutaneous access for the introduction of guide wire needed to place the screws.

All patients were monitored up to 24 months.

Results*:* 17 patients out of 19 (89.47%) healed with no evidence of complications or walking problems. One patient presented a loosening of a screw due to an unrecognized fracture at the time of treatment, another died following injuries sustained in the trauma.

Conclusion: According to our experience, CT guided operations guarantee greater accuracy than the traditional procedure in the operating room (86.8-97.2%) (Routt ML, 1997) (Keating JF, 1999), reduce the number of failures and favoring post-traumatic recovery and slim down the operation list.

Key words: Sacroiliac stabilization, CT Guide, Computed Tomography, Traumatology of the pelvis, Tile classification, Fractures of the pelvic ring, T-POD, ORIF, Sacroiliac fractures, Asnis III, Stryker, Orthopedic surgery, Interventional radiology under TC guide, multiplanar reconstructions.

Introduction

High energy pelvic fractures are potentially deadly, because of the massive haemorrhage that can occur.

Their treatment is made up of two phases: the first one ensures hemodynamic stability while the second one restores the mechanical functionality (Kurylo JC, 2012) (Carluzzo F, 2012) For the stabilization of the patient in the acute phase, a rapid reduction of the fracture is necessary with different restraints, which allow the pelvic diameters to be restored, to reduce the mobility of the fracture and to stop any internal hemorrhage.
For unstable fractures with an anterior opening, T-POD (Pelvic Orthotic Device) or an external fixator anchored on the iliac crest by transcutaneous route. In case of vertical shear, in addition to the external fixator, a trans-skeletal traction system is used (Bottlang M, 2002), (Routt Jr. ML, 2002), (Simpson T, 2002).

If abdominal and/or pelvic hemorrhages are present, the reduction is carried out together with the embolization of the affected vessels.

Depending on the type of fracture and the availability of spaces and equipment, different approaches and fixation systems can be used: the main methods of treatment of unstable pelvic ring fractures are percutaneous fixation by fluoroscopy and internal fixation (KellamJF, 1987) (Van den Bosch EW, 2002), (Beerekamp MS1, 2012)

In common clinical practice the percutaneous fixation is performed in the operating room under fluoroscopic guidance with an average execution time of 80' (Starr AJ, 2002) and is followed by a CT scan to verify the correct positioning of the means of synthesis: wrong positioning of the sacro-iliac screws are found in 2.8-13.2% of the CT controls (Routt ML, 1997), (Keating JF, 1999)

In case of badly positioned screws, a second surgical procedure is necessary, which in most cases is O.R.I.F. (Open Reduction Internal Fixation).

The O.R.I.F. technique is reserved in first instance only to patients who present contra-indications to the percutaneous method, such as vertical shear (decomposition of the joint in the longitudinal direction) and/or severe obesity, factors that hinder the safe positioning of the screws and increase the risk of invasion of the neural sacral foramen or penetration of the anterior cortex of the sacrum.

The complications of conventional surgery have mortality rates of 10% and morbidity of 52%. (McMurtry R, 1980), (PennalGF, 1980) the causes of morbidity include paresthesia of the ipsilateral limb, gait disturbances, low back pain and neurological disorders caused by nerve injury (Nelson DW, 1991).

The limits of fluoroscopy guided fixation determined the development of intraoperative CT-guided techniques.

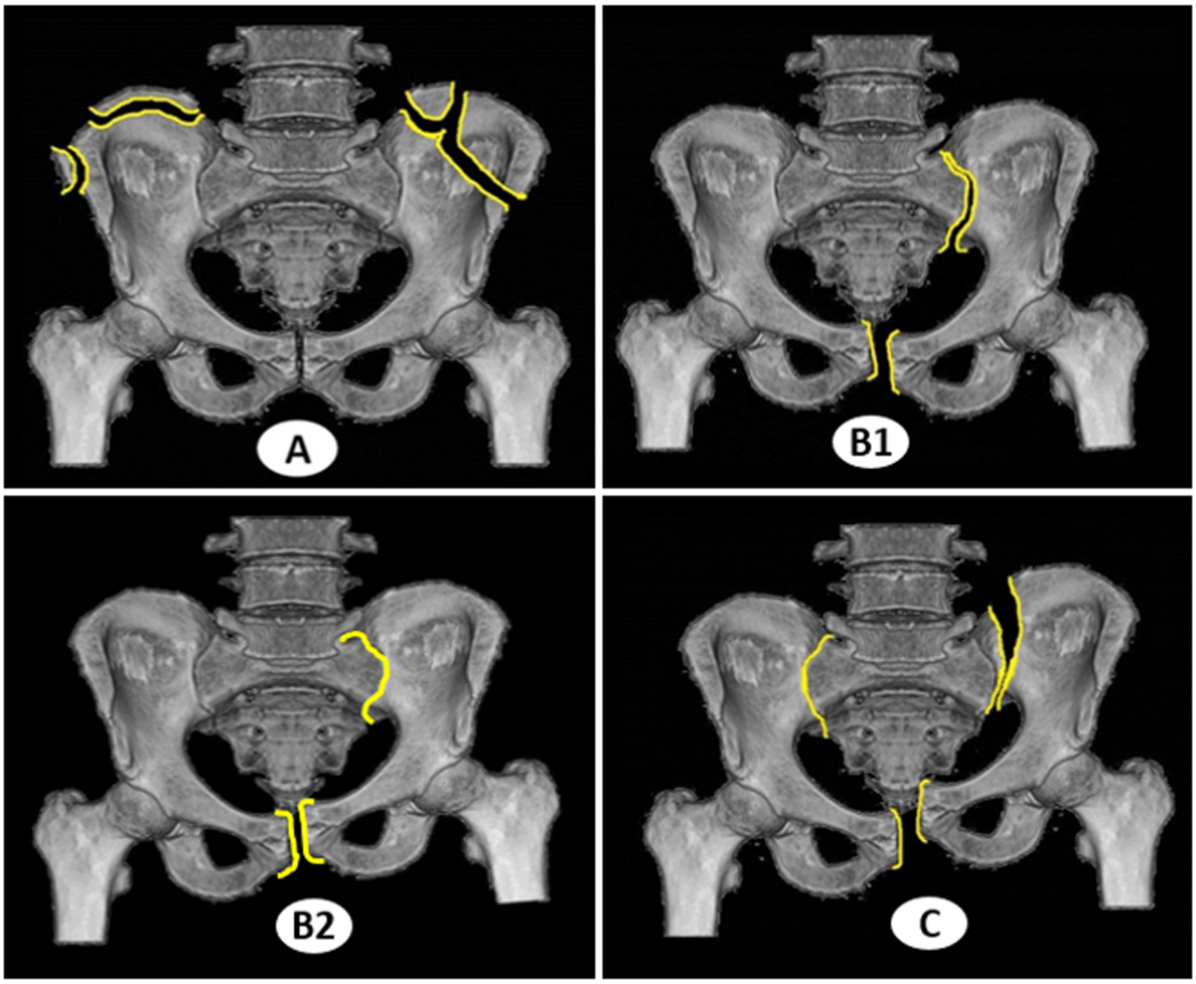
This study demonstrates the considerable advantages that this method offers compared to conventional techniques, such as panoramic views, multi-planarism, high precision and respect for the neighboring noble structures, as well as reduction of surgical times and blood loss. Vertical shear and severe obesity are absolute contraindications even to external sacroiliac fixation under CT guidance.

Materials e Method

Between December 2013 and February 2019, at the Emergency and Urgency Department of the Policlinico Umberto I in Rome, 19 patients with hip fractures, aged between 20 and 78 years (17 males and 2 females) were treated with minimally invasive CT guided screw placement.

For the evaluation of fractures the Tile classification was the most satisfactory for the clinical management of the patient, since it takes into account both the traumatic mechanism and the elementary lesions and the therapeutic and prognostic consequences that derive from it. In fact, the instability of the basin has repercussions on the entire skeletal and motor system; it is therefore obvious how an early stabilization guarantees a more rapid recovery.

All the patients in the study had type B and C fractures of the Tile classification: 18 from acute pelvic trauma (9 fallen, 9 car accident), 1 from non-traumatic cause.



Type A: Pelvic ring stable
- A1: fractures not involving the ring (i.e. avulsions, iliac wing or crest fractures)
- A2: stable minimally displaced fractures of the pelvic ring

Type B: Pelvic ring rotationally unstable, vertically stable
- B1: open book
- B2: lateral compression, ipsilateral
- B3: lateral compression, contralateral or bucket handle-type injury

Type C: Pelvic ring rotationally and vertically unstable
- C1: unilateral
- C2: bilateral
- C3: associated with acetabular fracture

Figure 1 Tile classification

All but one had multiple lesions that threatened vital functions and thus were classified as polytraumatized. 18 patients showed pelvic restraints when they came into the CT (13 TPODs, 5 external fixators), one had no restraint.

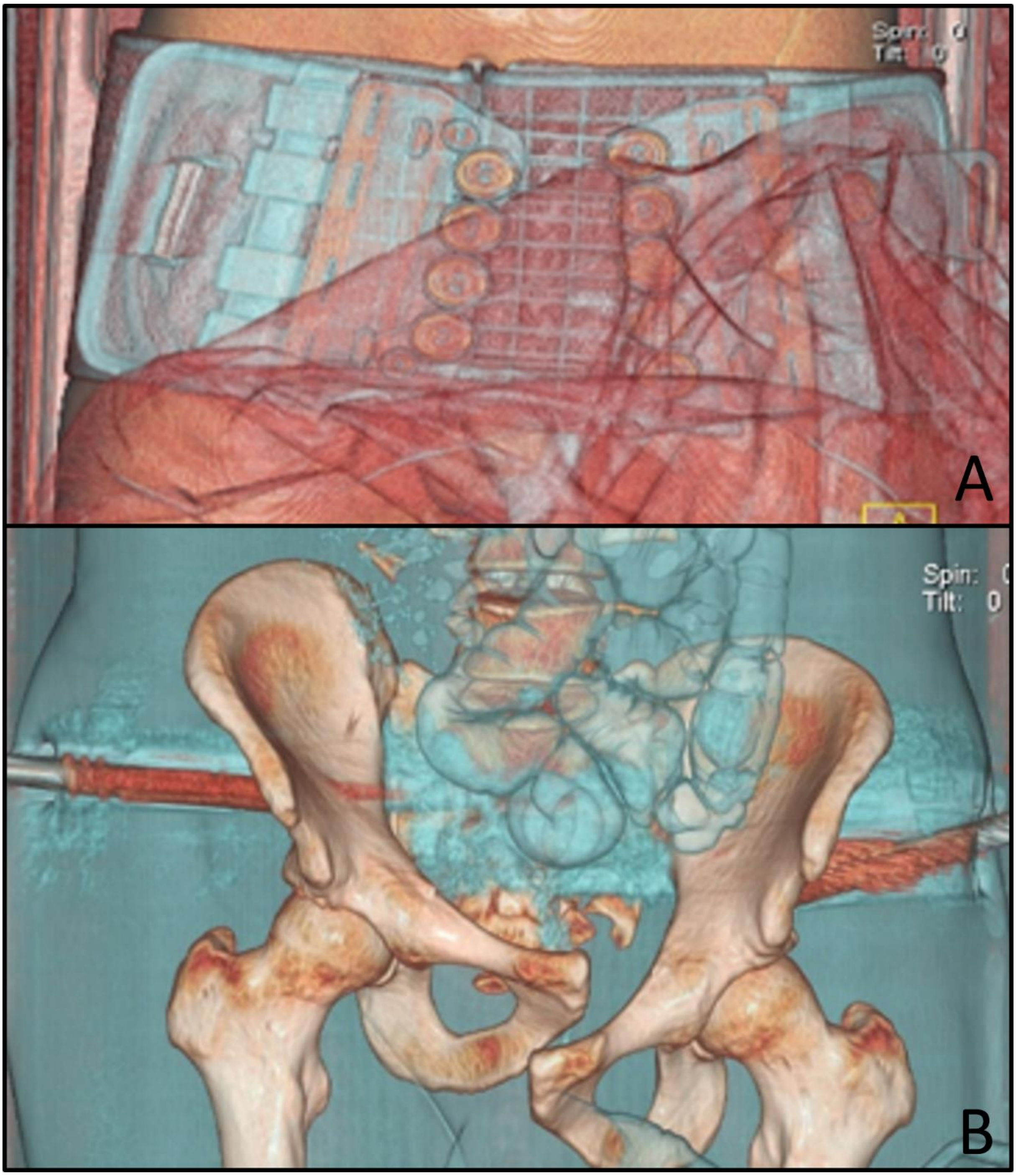


Figure 2 A) VRT of the T-POD, B) VRT of the external fixator

The machine used is a ***Siemens Somatom Sensation 16*** CT, (property of the emergency department of Policlinic Umberto I in Rome) equipped with a standard table, a control and post-processing panel provided with standard reconstruction software.

Figure 3 Computed Tomography

The room has an automatic breathing apparatus, an emergency cart, an aspirator, a defibrillator, a pulse oximeter and medical gases.

A handcrafted radiopaque grid made of metallic wires taken from the surgical equipment was used as a reference on the patient, The surgical devices used for the operation were scalpel no.11, guide wire for cannulated screws, surgical cutter and cannulated titanium

Figure 4 Devices used

screws (Asnis III,Stryker). Carbocaine was injected for local anesthetic with various types of needles with lenght between 8 and 15 cm (even an F.N.A needle).

The screws used are between 5 and 10 cm long and with a diameter between 6.5 and 8 mm. the number of screws used for each patient varies from 1 to 3.

The team is composed by an orthopedic surgeon, a radiologist (to define the type of fracture), a radiographer, an anesthesiologist (to support patients coming in almost all cases from intensive care) and a theatre nurse.

The protocol consists in a topogram, followed by a panoramic acquisition for preliminary evaluation (with spiral technique), multiple guide scans (with sequential or spiral technique) and a panoramic control scan (with spiral technique).

The guide scans provide images with a discreet contrast and spatial resolution (slice thickness 3-6 mm) even aiming at a low dose, which is required since the scanning is repeated until the the sacroiliac screws are positioned correctly.

Process

In order to perform the operation, the CT room must be cleaned and decontaminated and the surgical device must be sterilized. After being preventively treated with antibiotics, the patients are positioned supine with the target hip raised in order to have the sacro-iliac joint orthogonal to the table.

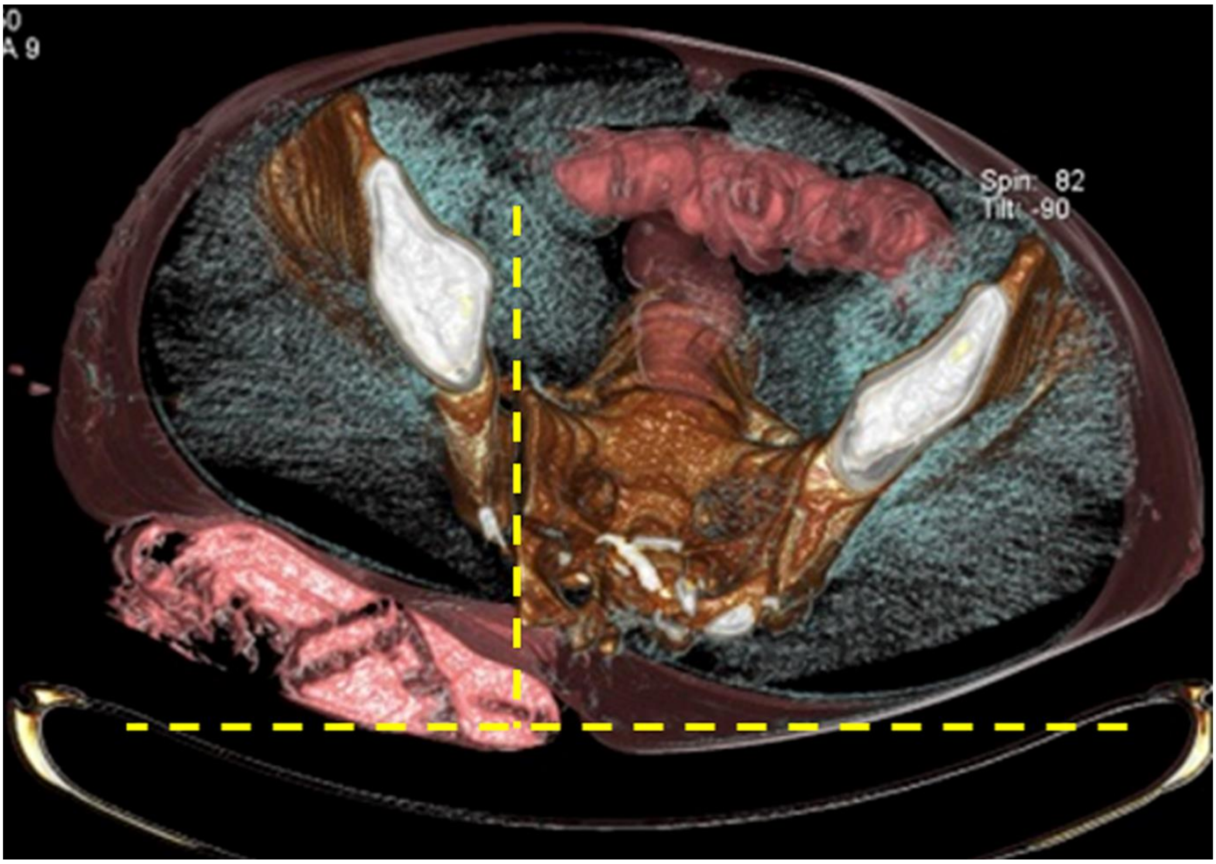


Figure 5 VRT image of patient's position

After the topogram (used for the positioning of the FoV) the entire pelvis is scanned in order to study the fracture and plan the better path for the guide wire: in order to do so, M.P.R reconstructions on different planes and geometric studies (distances and angles) are made After the research of the right slice for the introduction of the guide wire, the operator marks it with a grease pencil and aligns it with the laser, and then the interested area is disinfected.

After the demarcation of the sterile area the radiopaque grid (preventively sterilized) is positioned on the same. A sequential scan (inclined cranium-caudal or AP as the estimated angle of the screw), or a volumetric scan, is made.

With multiplanar reconstructions made using the radiopaque grid and the joint as reference points, can be calculated the angles and distances between the incision and the iliac crest or between the iliac crest and the sacrum in order to define the dimensions (length and diameter) of the screws that are going to be used for the stabilization.

Fundamental information for a correct preparation of the material needed for the operation.

When the access point is found, local anaesthetics can be injected in that area. In order to penetrate deep in the muscles a FNA needle is inserted with a certain angle (calculated before).

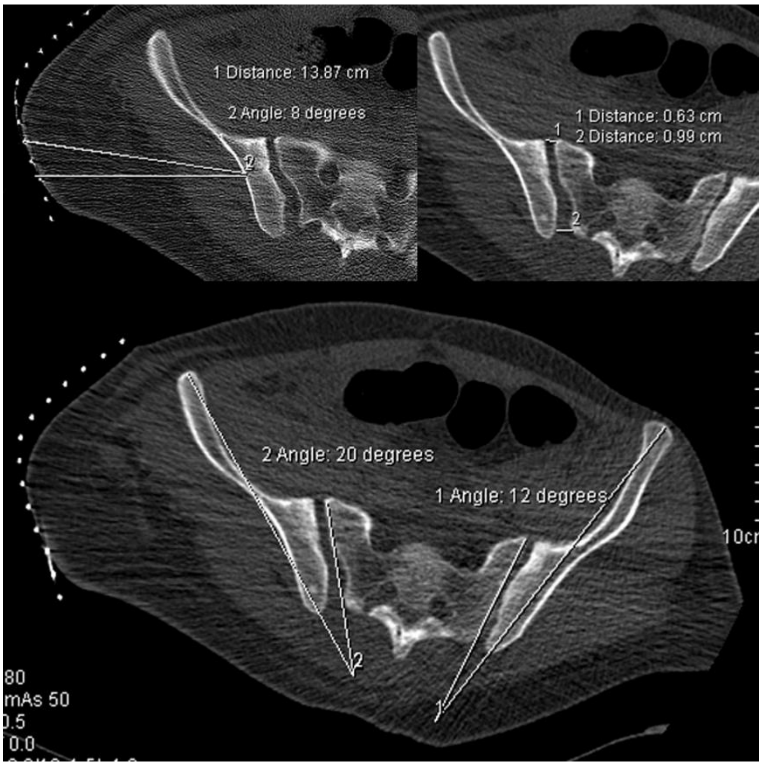


Figure 6 measurement of angles and distances

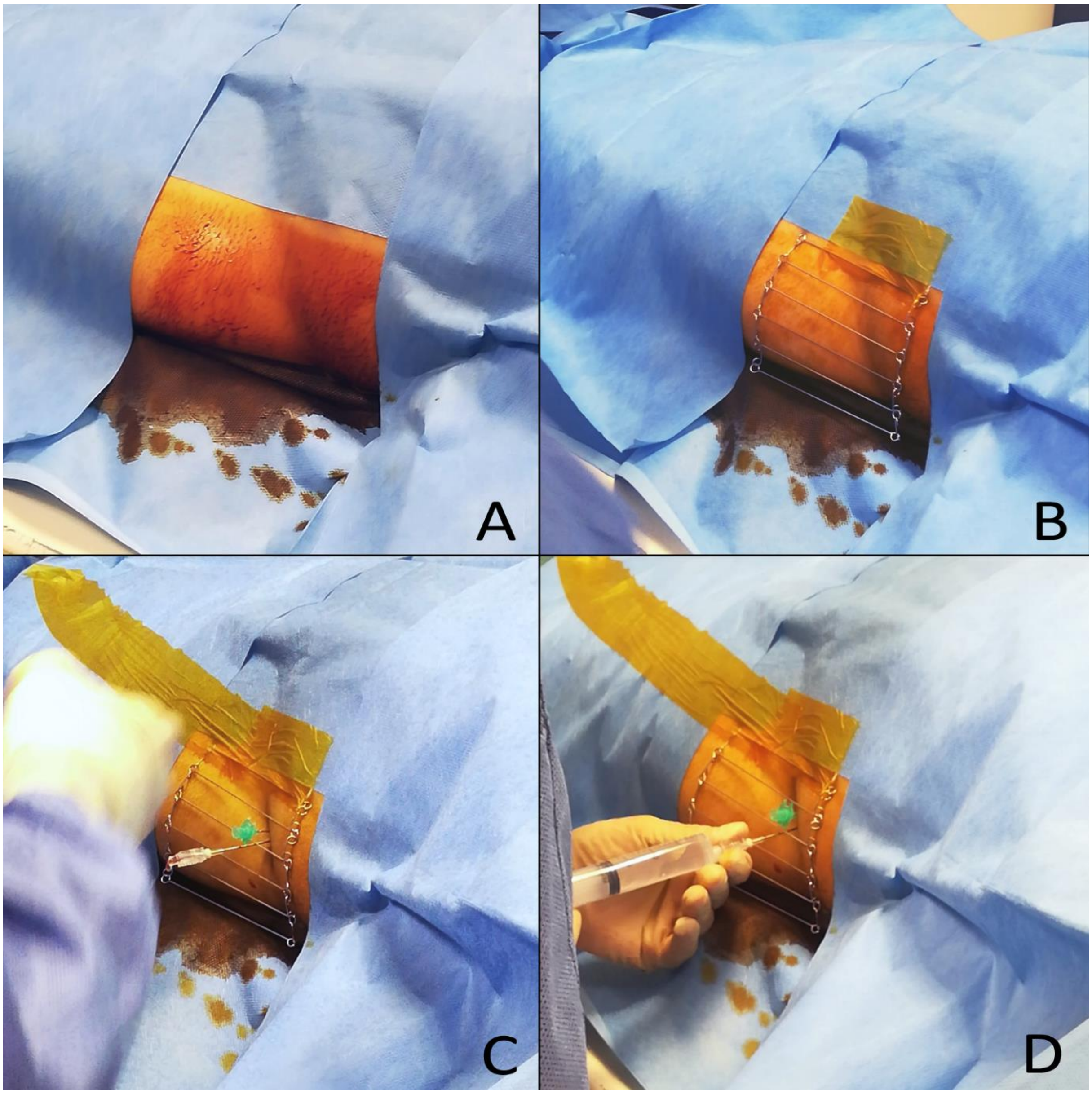


Figure 7 A) sterile zone, B) radiopaque grid, C) local anesthesia, D) deep anesthesia

Next multiple scans and multiplanar reconstructions are made to verify the placement of the guide needle (kept inside the patient). If the position is correct, a small incision with the scalpel is made and then the guide wire is inserted near the needle that must be removed. After the removal of the needle, another scan is made to verify the position of the guide wire. If the position is correct the surgeon proceeds with the insertion (the finding of the iliac crest is represented as a hindrance). A control scan is made to verify the orientation of the guide wire, which must be inserted inside the bone up to the first half of the vertebral body. Then geometric evaluations are made.

If the position is correct the surgeon inserts the bone drill and proceeds with the drilling of the iliac crest and the sacrum.

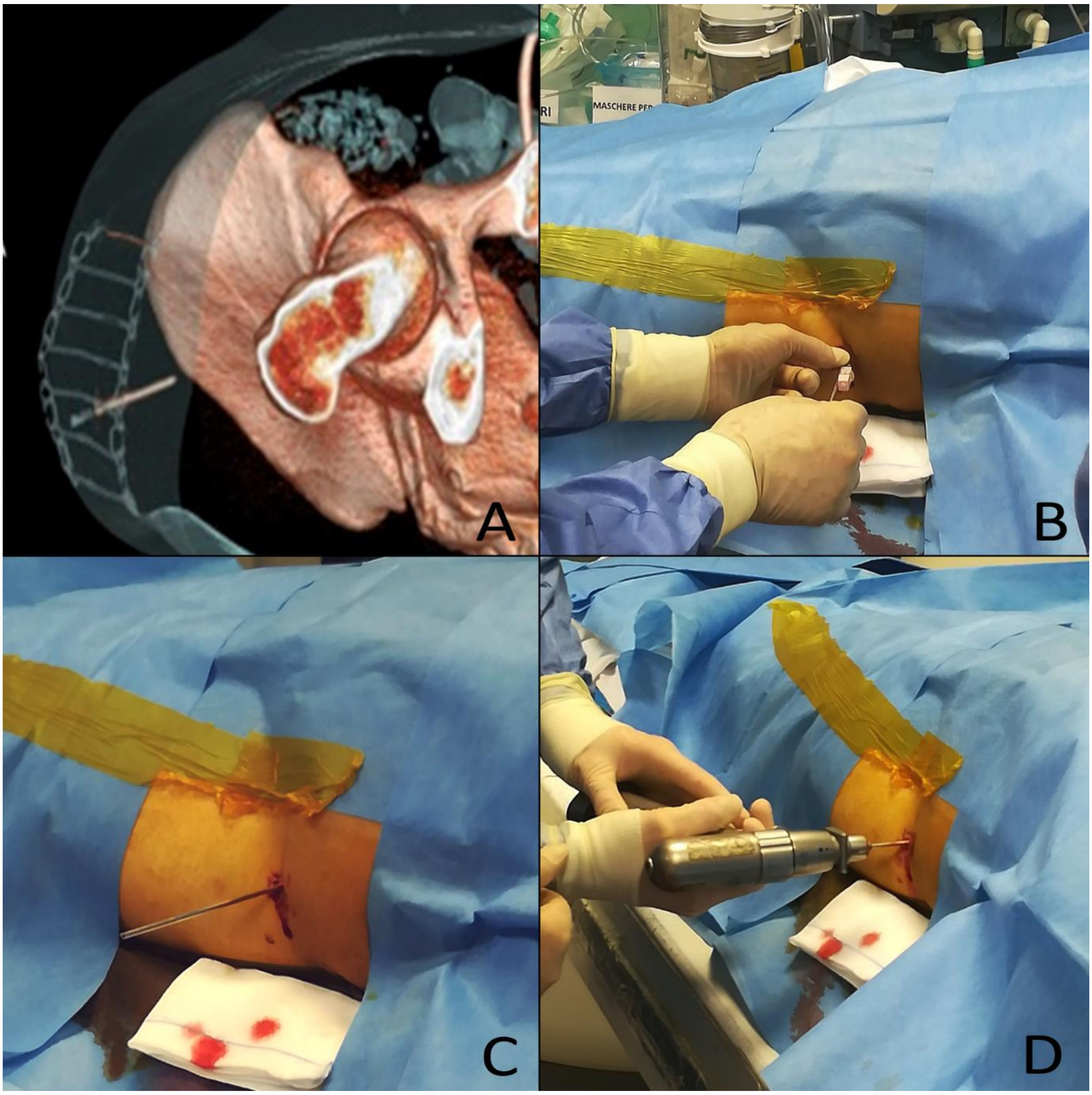


Figure 8 A) relation between Needle, grid and body, B) insertion of the guide wire, C) guide wire, D) deep insertion

The drill is pulled out and the screw is inserted and tightened on the path of the guide wire until the end of the path. Thus, the fracture is reduced.

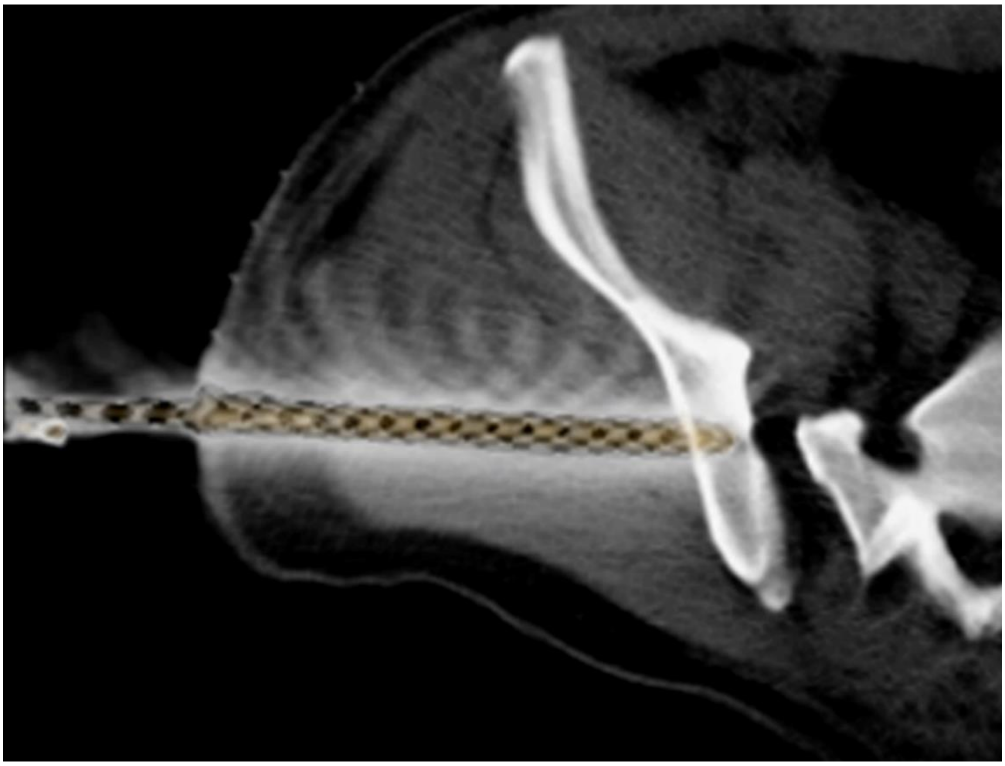


Figure 9 Drill

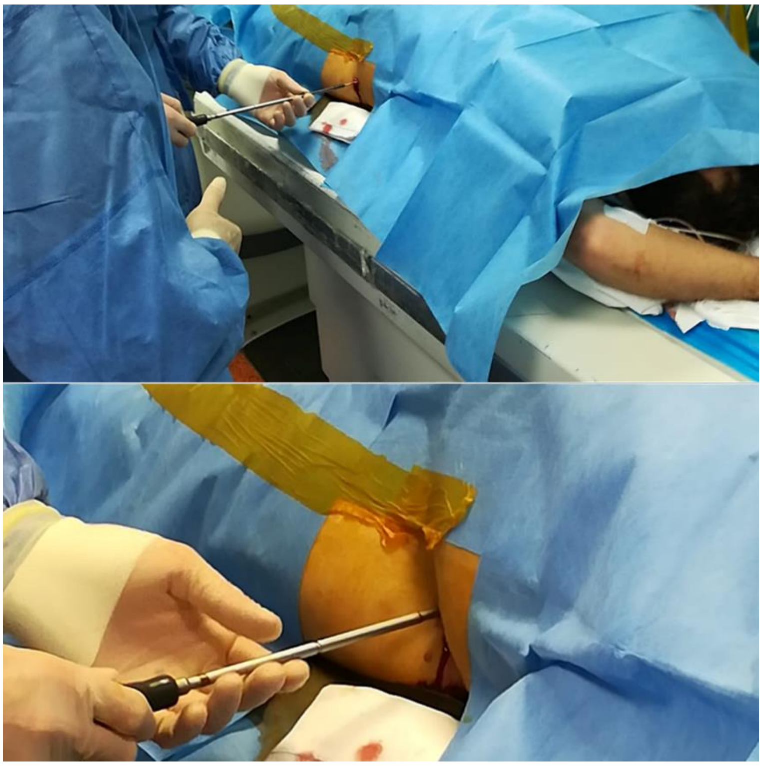


Figure 10 Insertion of the cannulated screw and final twist

A volumetric scan of the entire pelvis is made to verify the position of the screw in relation to the joint and the nerves and the symmetry between the hips. The operation can be repeated for the insertion of a second ipsilateral screw (with or without a parallel guide) or for the insertion of a contralateral screw.

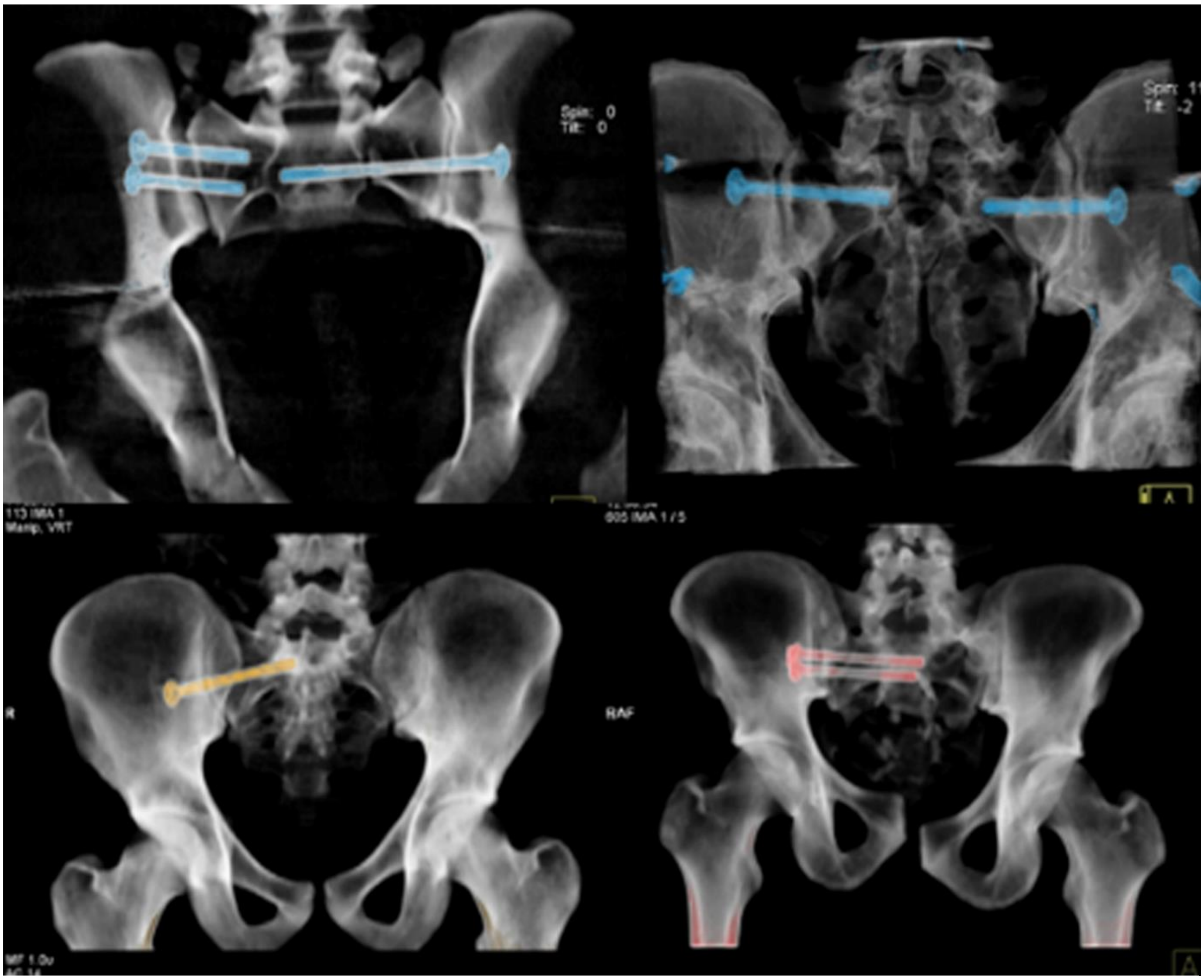


Figure 11 VRT reconstructions of the pelvis with the screws

The operation ends with the suture of the surgical incision and with the cleaning of the skin. Now the patient can rest until the healing is complete.

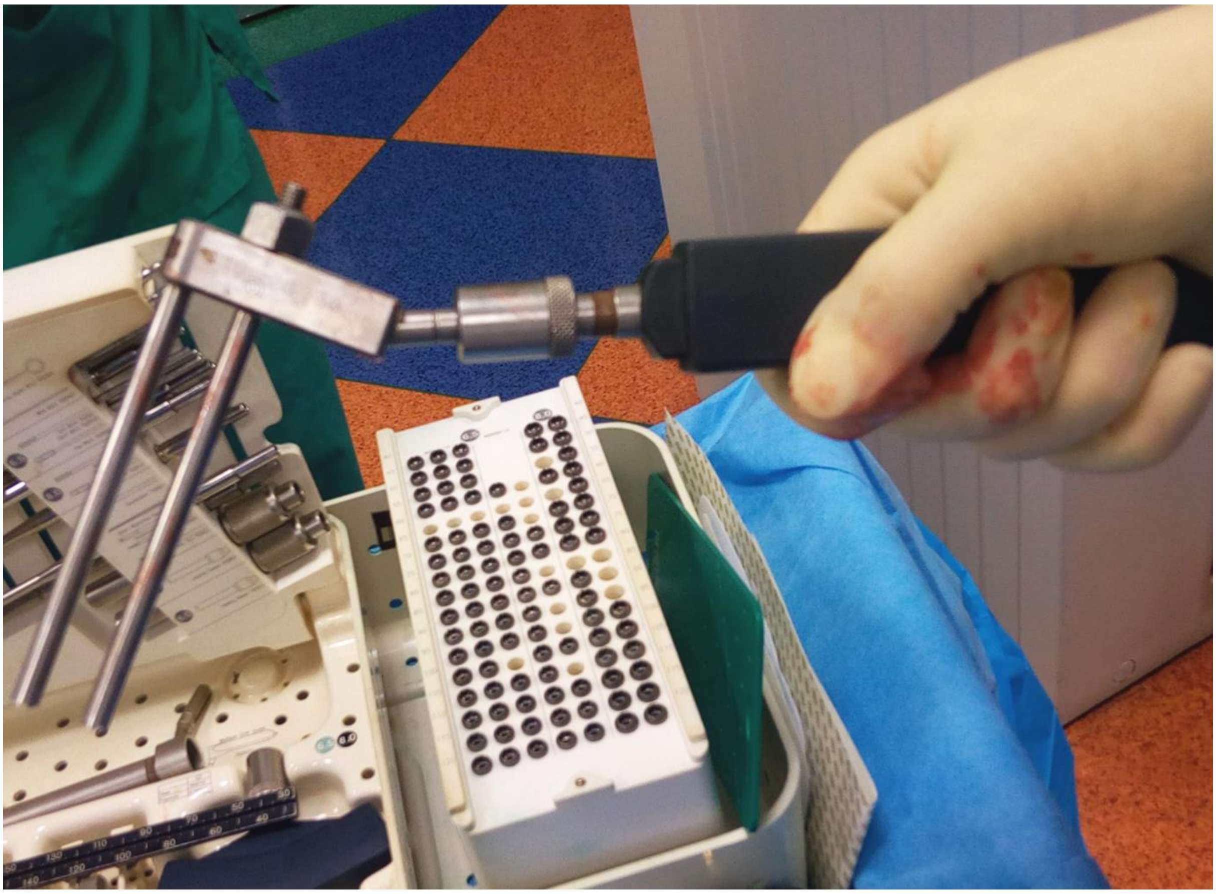


Figure 12 parallel guide

Results

Mean time for the operation in our experience was about 92'. Time was calculated from the topogram to the last scan. The operations took minimum 57' and maximum 150': time gradually reduced with the increasing experience of the team. In the cases that needed more than one screw time did not increase proportionally to the number of screws but only because of the material time needed for the insertion of the screws (2 ipsilateral screws 126', 3 screws 150').

The estimate and interpretation of the images, the calculation of distances, angles and geometry of the joint were the most long-lasting procedures. Total time took to complete the operation influenced the dose erogation to the patient: even if it gradually reduced, it remained moderately high. Careful study of the first four cases allowed us to find the right CT protocol that do not go beyond 1200 Total DLP (Dose Length Product) and 22mSv of Effective Dose; our imperative purpose is to reduce such value. Care Dose 4D allowed us to reduce the dose and preserve good contrast and spatial resolution: mA 50, kV 80, rotation time 0,5", detectors arrangements 16X1,5 or 12X1,2. For the panoramic scans we used a 1.0 pitch, while for the control scans we used a 1.2 pitch. Blood loss was minimal because of the discreet length of the incision (1 cm).

The opportunity for further adjustments is evaluated on the patient's condition (habitus, metal artifacts from external fixator), with the imperative tendency to reduce the radiation dose.

In all cases the blood loss was minimal, since the incision made for the introduction of the screw is about 1 cm, unlike the fluoroscopic guide method which involves an average loss of 50 ml (range 5-300 ml) (Starr AJ, 2002)

At the end of the treatment, all patients returned to their respective ward.

In similar works the clinical follow-up is performed in a period between 12 and 48 months (Sciulli RL, 2007), (Won-Sik Choy, 2004), (Ziran BH, 2003)while in our case study the first check was planned 1 week after surgery.

Table 1: Outcome

OPERATION DAY		12/12/13	10/01/14	22/01/14	19/02/14	11/02/15	26/02/15	25/03/15	04/05/15	03/09/15	06/10/15	22/12/15	27/07/16	12/10/16	28/03/17	13/04/17	11/05/17	31/08/18	29/11/18	14/02/19
PATIENT		**1**	**2**	**3**	**4**	**5***	**6**	**7#**	**8**	**9@**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
1 WEEK	G	0	0	0	2	0	0	†	0	0	0	0	0	0	0	0	0	0	0	0
	M	0	0	0	2	0	0	†	0	0	0	0	0	0	0	0	0	0	0	0
	A	1	1	1	0	1	2	†	1	2	1	1	1	2	1	2	1	1	1	2
	P	1	1	2	0	1	0	†	2	3	1	1	3	1	1	2	1	1	1	1
2 MONTHS	G	2	2	2	3	2	2	†	2		2	2	1	2	2	2	2	2	2	2
	M	2	2	2	3	2	2	†	2		2	2	1	2	2	2	2	2	2	2
	A	1	1	1	0	1	2	†	1		1	1	1	2	1	2	1	1	1	2
	P	0	0	0	0	0	0	†	0		0	0	0	0	0	0	0	0	0	0
6 MONTHS	G	3	3	3	3	3	3	†	3		3	3	2	3	3	3	3	3		
	M	3	3	3	3	3	3	†	3		3	3	3	3	3	3	3	3		
	A	1	1	1	0	1	2	†	1		1	1	1	2	1	2	1	1		
	P	0	0	0	0	0	0	†	0		0	0	0	0	0	0	0	0		
12 MONTHS	G	3	3	3	3	3	3	†	3		3	3	3	3	3	3	3			
	M	3	3	3	3	3	3	†	3		3	3	3	3	3	3	3			
	A	1	1	1	0	1	2	†	1		1	1	1	2	1	2	1			
	P	0	0	0	0	0	0	†	0		0	0	0	0	0	0	0			
24 MONTHS	G	3	3	3	3	3	3	†	3		3	3	3	3						
	M	3	3	3	3	3	3	†	3		3	3	3	3						
	A	1	1	1	0	1	2	†	1		1	1	1	2						
	P	0	0	0	0	0	0	†	0		0	0	0	0						

Legend:
G (gait), M (mobility), A (asymmetry), P (pain).

RATING; 0 absent, 1 not very present, 2 present, 3 very present

* No trauma, # died due to the severity of the trauma, @ location of the screw and new operation 10/15/2015

The results of the treatment were positive in all cases as no complications occurred. Even the long-term results were satisfactory since the patients did not present any functional problems related to walking.

As in the traditional procedure, slight asymmetries may remain and their entity is directly related to the complexity of the initial fracture and not to the choice of the procedure used.

Only in one patient the screw dislocated after 2 weeks from the operation because of therapeutic movement during his convalescence. When we reevaluated the case, we found out an unacknowledged contralateral fracture of the sacrum.

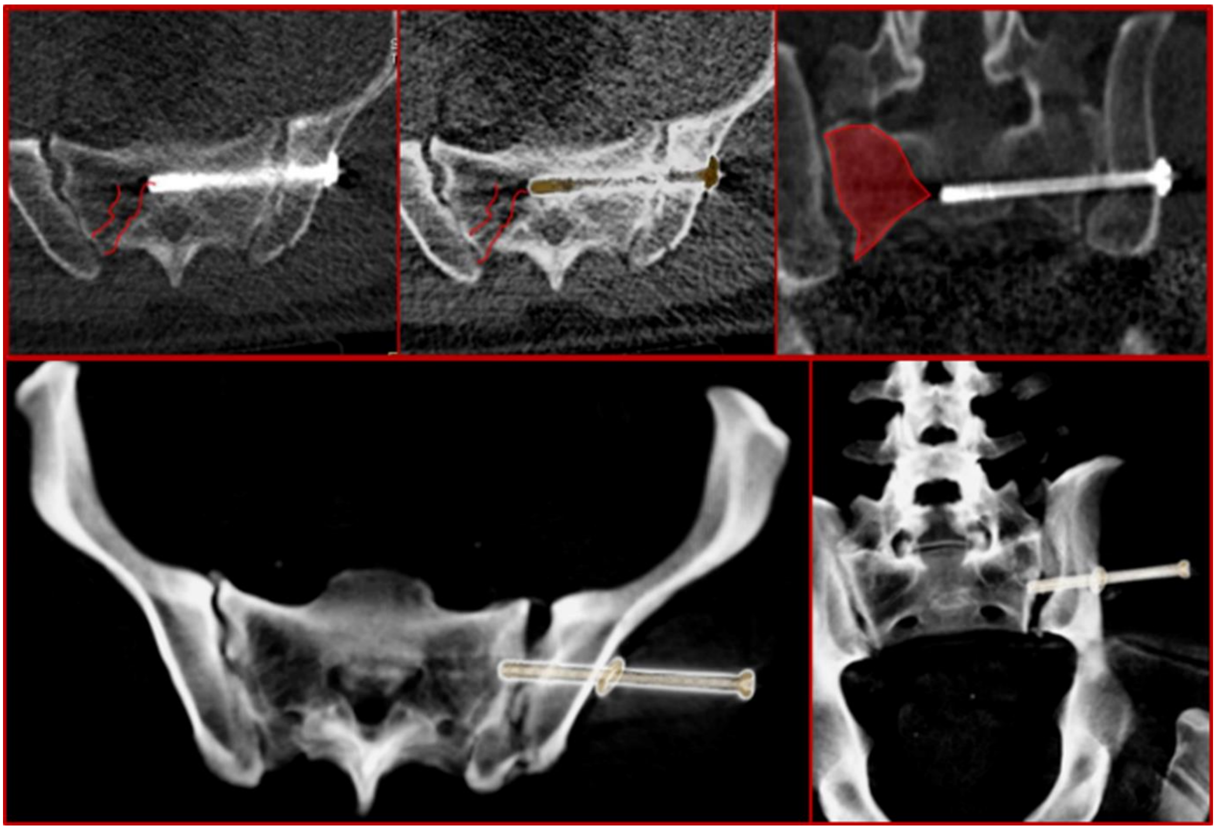


Figure 13 unacknowledged fracture and dislocated screw

Discussion

The limits of the fluoroscopic guide have led to the research of new methods.

Since fluoroscopy is a two-dimensional technique, it is difficult to visualize the posterior structures of the pelvis (ligaments and muscles).

In particular, it is difficult to localize the sacral foramina through which the nerve roots emerge.

The problem gets even worse in obese patients.

In literature a perforation rate of the sacrum by screws positioned under fluoroscopic guidance of over 68% and an incidence of neurological damage greater than 7.9% is reported (Routt Jr. ML, 2002), (Duwelius PJ, 1992).

This method involves a high exposure to ionizing radiation both of the patient and the medical and paramedical team (Kahler, 2003).

The average fluoroscopy time reported in the literature is 18' (Starr AJ, 2002).

Some studies report that most experienced surgeons require an average of 126 "for the placement of sacroiliac screws and 200" for the retrograde positioning of the screws on the superior pubic branch (Routt ML Jr, 1995), (Routt ML, 1997).

The maximum exposure dose reported for the patient is 40mSv/min, for the surgeon there is a deep exposure of 0.2mSv/min and a superficial exposure of 0.29mSv/min, for the rest of the team (anesthesiologist and nurse nurse) maximum exposure corresponds to 0.02 mSv/min (Mehlman & Di Pasquale, 1997).

The examination requires intestinal preparation with enema (essential for the correct identification of the bone structures that need to be repaired).

It is also necessary to use a special radiolucent bed, with the possibility of longitudinal translation in order to allow the movements of the image intensifier.

However, the treatments carried out under fluoroscopic guidance allow a very accurate anesthetic management, a greater guarantee of sterility and the possibility of transforming the procedure into open surgery: these advantages have made it until now the most used technique.

Percutaneous CT guided fixation allows a considerable reduction of the radiation exposure (Day AC, 2007), (Zwingmann J, 2009), (Collinge C, 2005), (Mosheiff R, 2004), it also appears to be practically free from complications.

In fact, CT allows a more accurate positioning of the screws thanks to the direct measurement of their length, it avoids the penetration of the sacral foramina with probable consequent neural lesion and the perforation of the anterior cortex of the sacrum from which may result vascular damages (Nelson DW, 1991), (Tonetti J, 1998)

The sacroiliac stabilization through CT guide has proved to be a valid technique. According to the literature it gives the possibility of performing an easy non-invasive percutaneous osteosynthesis (Ziran BH, 2003), (Richard H. Daffner, 2013), (Berton R. Moed, 2006), (Gandhi, et al., 2017).

Table 2: Accuracy

Authors	Article	Patients	Accuracy
Nelson DW, D.P.	"CT-guided fixation of sacral fractures and sacroiliac joint disruptions" - 1991	8	100%
Duwelius PJ, V. A.	"Computed tomography-guided fixation of unstable posterior ring disruption" - 1992	13	100%
Ziran BH, S. W.	"Iliosacral screw fixation of the posterior pelvic ring using local anaesthesia and computerised tomography" - 2003	-	100%
Berton R. Moed, B. L.	"MDw S2 Iliosacral Screw Fixation for Disruptions of the Posterior Pelvic Ring: A Report of 49 Cases" – 2006	49	98%
Gandhi G. et al.	"Estabilizacão sacroilíaca percutânea guiada por tomografia computadorizada nas fraturas pélvicas instáveis: uma técnica segura e precisa" - 2017	6	100%
Spanò F. et Al	**"**CT-guided sacroiliac screws placement**"-** 2019	19	100%

The collaboration between all the members of the team was fundamental, in particular the communication between the TSRM and the orthopedist.

It must be considered that for the orthopedic surgeon and the nursing staff who participated in this study it was the first experience of percutaneous CT-guided treatment of pelvic fractures; while, the radiographer presented a multi-year experience in the field of CT-guided interventional radiology, even if in different fields from the orthopedic one (drainage, FNA, thermal ablation, etc.).

The experience of the orthopedic surgeon in traditional ileosacral stabilization and the mastery of the radiographer in the evaluation and perception of space with CT imaging, have represented the winning combination for the purpose.

The use of low dose protocols significantly reduces exposure of the patient but produces images characterized by artifacts and low spatial resolution that require experience and specific training to be correctly analyzed and to avoid misinterpretation.

Conclusion

Our study shows that the results of CT-guided sacroiliac stabilization are better than those obtained with the traditional procedure, as there were no complications from incorrect screw positioning (100 % accuracy, versus 86.8-97.2% fluoroscopy) and the outcomes proved to be similar to the ones obtained with traditional operations correctly performed (Tonetti J, 1998) (Day AC, 2007).

In our experience CT guided fixation has proved to be a safe, reliable, fast, reproducible and an advantageous method for patients and operators both in terms of dose exposure and minimal incidence of complications such as: malposition, infections, excessive blood loss, as well as for the healthcare facility in economic and resource terms.

The benefits for the patient are a better outcome, less pain, quick functional recovery, fewer or no side effects due to anesthetic drugs.

For these reasons in our hospital we currently use the CT guide as first choice technique for the treatment of sacroiliac instability.

References

Beerekamp MS1, S. G. (2012). Accuracy and consequences of 3D-fluoroscopy in upper and lower extremity fracture treatment: a systematic review. *Eur J Radiol., 81(12):19-28*.

Berton R. Moed, B. L. (2006). MDw S2 Iliosacral Screw Fixation for Disruptions of the Posterior Pelvic Ring: A Report of 49 Cases. *Journal Orthopedic Trauma, 20*, 378-383.

Bottlang M, K. J. (2002). Emergent management of pelvic ring fractures with use of circumferential compression. *J Bone Joint Surg Am, suppl2:43-7.*(84).

Carluzzo F, L. E. (2012). *Le fratture dell'anello pelvico: eziopatogenesi, classificazione e scelta del trattamento.* Catania: Dipartimento di Specialità Medico – Chirurgiche Sezione di Ortopedia e Traumatologia, Università degli Studi di Catania.

Collinge C, C. D. (2005). Standard multiplanar fluoroscopy versus a fluoroscopically based navigation system for the percutaneous insertion of iliosacral screws: a cadaver model. *Journal Orthopedics Trauma, 19*, 254-258.

Day AC, S. P. (2007). The accuracy of computer-assisted percutaneous iliosacral screw placement. *Clinical orthopaedics and related research, 463*, 179-186.

Duwelius PJ, V. A. (1992). Computed tomography-guided fixation of unstable posterior ring disruption. *Journal Orthopedic Trauma, 6*(4), 420-426.

Gandhi, G., Vijayvargiyaa, M., Shettya, V., Agashea, V., Maheshwarib, S., & Monteiro, J. (2017, Marzo 2). Estabilização sacroilíaca percutânea guiada por tomografia computadorizada nas fraturas: uma técnica segura e precisa. *Revista Brasileira de ortopedia, 53*(3), 323–331.

Kahler, D. (2003). Percutaneous screw insertion for acetabular and sacral fractures. *Techniques in Orthopaedics, 18*, 174-183.

Keating JF, W. J. (1999). Early fixation of the vertically unstable pelvis: the role of iliosacral screw fixation of the posterior lesion. *Journal Orthopedic Trauma*(13), 107-13.

KellamJF, M. R. (1987). The unstable pelvic fracture. Operative treatment. *Orthopedic Clinics of North America*, 25-41.

Koo H, L. M. (2008). 64. Interobserver reliability of the Young-burgess and Tile classification systems for fractures of the pelvic ring. . *J Orthop Trauma., 22:379–84.*

Kurylo JC, T. P. (2012). Initial management and classification of pelvic fractures. *61:3–18*.

McMurtry R, W. D. (1980). Pelvic disruption in the polytraumatized patient: a management protocol. *Clinical orthopaedics and related research*, 22-30.

Mehlman, C., & Di Pasquale, T. (1997, Aug.). Radiation exposure to the orthopaedic surgical team during fluoroscopy: "how far away is far enough?". *Journal Orthopaedic Trauma, 11*(6), 392-8.

Mosheiff R, K. A. (2004). First generation computerized fluoroscopic navigation in percutaneous pelvic surgery. *Journal Orthopedic Trauma, 18*, 106-111.

Nelson DW, D. P. (1991). CT-guided fixation of sacral fractures and sacroiliac joint disruptions. *Radiology, 180*, 527-532.

PennalGF, T. M. (1980). Pelvic disruption: assessment and classification. *Clinical orthopaedics and related research*, 12-21.

Richard H. Daffner, M. R. (2013). MD CT-Guided Iliosacral Screw Placement. *Seminars Musculoskelet Radiology*(17), 407-415.

Routt Jr. ML, F. A. (2002). Circumferential pelvic antishock sheeting: a temporary resuscitation aid. . *J Orthop Trauma, 16:45-8*.

Routt ML Jr, S. P. (1995). The retrograde medullary superior pubic ramus screw for the treatment of anterior pelvic ring disruptions: a new technique. *Journal Orthopedic Trauma*(9), 35-44.

Routt ML, S. P. (1997). Ileosacral screw fixation: early complications of the percutaneous technique. *Journal Orthopedic Trauma*(11), 584-9.

Sciulli RL, D. R. (2007). CT-guided iliosacral screw placement: technique and clinical experience. *AJR Am J Roentgenol., 188(2):W181-92.*

Simpson T, K. J. (2002). Stabilization of pelvic ring disruptions with a circumferential sheet. . *J Trauma , 52:158-61*.

Starr AJ, W. J. (2002). Percutaneous screw fixation of fractures of the iliac wing and fracture-dislocations of the sacro-iliac joint (OTA Types 61-B2.2 and 61-B2.3, or Young-Burgess "lateral compression type II" pelvic fractures). *Journal Orthopedic Trauma, 16*, 116–123.

Tonetti J, C. L. (1998). Percutaneous iliosacral screw placement using image guided techniques. *Clinical orthopaedics and related research, 354*(354), 103-110.

Van den Bosch EW, V. Z. (2002). Fluoroscopic positioning of sacroiliac screw in 88 patients. *Journal of Trauma*, 53(1):44-48.

Won-Sik Choy, M. B.-S.-Y.-H.-H. (2004). Iliosacral Screw Fixation of the Posterior Pelvic Ring Using Local Anesthesia and Computerized Tomography. . *J. of Korean Orthop. Assoc, 39: 72*.

Ziran BH, S. W. (2003). Iliosacral screw fixation of the posterior pelvic ring using local anaesthesia and computerised tomography. . *J Bone Joint Surg Br. , (3):411-8*.

Zwingmann J, K. G. (2009). Computer-navigated iliosacral screw insertion reduces malposition rate and radiation exposure. *Clinical Orthopedic Related Research, 467*(7), 1833–1838.