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Review Article

A perspective on wrong level, wrong side, and wrong site spine surgery

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ABSTRACT

Background: Four of the most common "errors" in spine surgery include: operating on the wrong patient, doing the wrong procedure, performing wrong-level surgery (WLS), and/or performing wrong-sided surgery (WSS). Although preoperative verification protocols (i.e. Universal Protocol, routine Time-Outs, and using the 3 R's (i.e. right patient, right procedure, right level/side)) have largely limited the first two "errors," WLS and WSS still occur with an unacceptably high frequency.

Methods: In 20 studies, we identified the predominant factors contributing to WLS/WSS; unusual/anatomical anomalies/variants (i.e. sacralized lumbar vertebrae. lumbarized sacral vertebra, Klippel-Feil vertebrae, block vertebrae, butterfly vertebrae, obesity/morbid obesity), inadequate/poor interpretation of X-rays/fluoroscopic intraoperative images, and failure to follow different verification protocols.

Results: "Human error" was another major risk factor contributing to the failure to operate at the correct level/side (WLS/WSS). Factors comprising "human error" included; surgeon/staff fatigue, rushing, emergency circumstances, lack of communication, hierarchical behavior in the operating room, and failure to "speak up".

Conclusion: Utilizing the Universal Protocol, routine Time Outs, and the 3 R's largelly avoid operating on the wrong spine patient, and performing the wrong procedure. However, these guidelines have not yet sufficiently reduced the frequently of WLS and WSS. Greater recognition of the potential pitfalls contributing to WLS/WSS as reviewed in this perspective should better equip spine surgeons to avert/limit such "errors" in the future.

Keywords: Lumbar surgery, Multiple intraoperative X-ray/fluoroscopy techniques, Right level, Right patient, Right procedure, Right (Correct) side, Universal Protocols, Avoid Wrong Level (WLS)/Wrong Side Spine Surgery (WSS)

INTRODUCTION

Four of the most common "errors" in spine surgery include: operating on the wrong patient, performing the wrong procedure, operating at the wrong-level (WLS), and operating on the wrong-side (WSS) (i.e. includes wrong site surgery (WSS) as well).[1,2,4-10,13,14,16,18,19,20] Although routine use of the Universal Protocol, Time-Outs, and the 3 R's (i.e. right patient, right procedure, right location/side) should largely limit/eliminate the first two "errors," WLS and WSS still occur with an unacceptable frequency.[1,2,4-7,10,12,14,16-20] Here, we reviewed the incidence of WLS and WSS in 20 studies, and looked at the major factors contributing to these "errors;" spinal anomalies/anatomic variants, and failure to obtain adequate intraoperative X-rays/Fluoroscopic images (i.e. inadequate number, inadequate quality, poor/misinterpretation of X-rays/fluoroscopic images). Additionally, "human errors"

contributed to WLS/WSS (i.e. including the lack of surgeon/staff preparedness, hierarchical behaviors interfering with honest communication (i.e. failure to "speak up"), fatigue, rushing/emergent procedures, and others).[1,2,4-7,10,12,14,16-20] Our aim in highlighting the main failures contributing to WLS/WSS/WSSS should help limit/eliminate them in the future.

INCIDENCE OF WRONG LEVEL SURGERY (WLS)

Wrong level spine surgery (WLS) is not that rare. [Table 1].[1,4,8,15] In 2007, Jhawar *et al*. and in 2008 Ammerman and Ammerman documented that wrong level cervical diskectomy occurred in from 6.8 to 7.6/10,000 cases/year, while wrong level lumbar diskectomies occurred in from 4.5 to 12.8/10,000 cases/year.[1,8,15] Using the 1995–2005 Joint Commission Sentinel Event Statistics Database, Devine *et al*. (2010) observed that wrong site spine surgery (WSSS) was the second most frequently encountered adverse event, and determined its frequency was 12.8% (i.e. occurring in 455/3548 spinal procedures); in the literature, the incidence of WSSS varied from 0.9 to 4.5 cases/10,000 spinal operations per year.[4]

INCIDENCE OF WLS FOR INDIVIDUAL SPINAL SURGEONS OVER THEIR ENTIRE CAREERS

Notably, 50–67% of spine surgeons have directly experienced WLS over their careers [Table 1].[12,14,20] Mody *et al*. (2008) observed that 207 (50%) neurosurgeons had experienced WLS (spinal) once or more during their careers; the overall incidence was 1/3110 spinal cases.[14] Watts *et al*. (2019) reported the same 50% incidence of WLS over spine surgeons' careers, a frequency distinctly unchanged by the 11 year interval between the two studies.[20] Interestingly, Mayer *et al*. (2014) reported a higher 67% incidence of WLS involving thoracolumbar procedures over surgeons' careers; this frequency was somewhat higher utilizing X-ray (56%) alone vs. fluoroscopy (44%) to intraoperatively confirm the correct spinal operative levels.[12]

FREQUENCY OF INITIAL WRONG LEVEL EXPOSURE (WLE) OR UNINTENDED LEVEL SURGERY (ULS)

Little attention has been given to the 0.3–4.3–15% incidence of initial wrong level exposure (WLE) or unintended level spine surgery (ULS). WLE/ULS is defined by recognizing during the index procedure that the initially exposed level was incorrect, but that this "error" was corrected prior to closure [Table 1].[3,12,14] When Mody *et al*. (2008) surveyed 415 neurosurgeons, 64 (15%) had at least 1 instance in which a wrong level was initially exposed; in these cases, the "error" was immediately corrected without the need for a second operation.[14] Such "errors" were attributed to a multitude of factors; rare anatomical variations, failure to identify anatomical landmarks, and obesity/unusual body habitus.[12,14] Dablouk *et al*. (2019) recommended requiring needle placement in fixed anatomic structures (i.e. facet joint or spinous process) to avoid these "errors". They also emphasized performing adequate preoperative and intraoperative "Time Outs", and improving communication between the operating personnel/staff.[3]

USE OF THE UNIVERSAL PROTOCOL, TIME OUTS, AND THE 3 R'S TO AVOID WRONG LEVEL SURGERY (WLS), WRONG SIDE SURGERY (WSS), AND WRONG SITE SURGERY (WSSS)

Multiple protocols (i.e. Universal Protocol- JCAHO (Joint Commission on Accreditation of Healthcare Organizations), Time Outs, and the 3R's) are aimed at avoiding WLS, WSS, and WSSS [Table 1].[1,2-10,12,14,16-20] Clarke *et al*. (2008) used the 3 step R protocol (i.e. right patient, right side, and right level), Time Outs, and marking the correct site to avoid WSSS.[2] Palumbo *et al*. (2013) recommended not only using the 3 R protocol, but also emphasized that surgeons follow strict regimens to ensure operating at the correct vertebral levels.[16] In 2020 Devine *et al*. reevaluated their JCAHO-based Universal Protocol data to better limit/eliminate WSSS.[4] Nevertheless, several authors observed the continued failure to elminate WSS that continued to occur in up to 1/3 of cases.[9,10]

REASONS THE UNIVERSAL PROTOCOL, TIME OUTS, AND 3 R'S FAIL TO AVOID WLS, WSS, AND WSSS

There are multiple causes for the "errors" resulting in WLS, WSS, and WSSS.[1,2,4-7,9,12,14,17-20] The most common cause includes anatomic variants (i.e. transitional levels (sacralized lumbar vertebra/lumbarized sacral vertebra), lumbar ribs, butterfly vertebrae, hemivertebra, block/fused vertebra, spinal dysraphism, Kilppel-Feil vertebrae in the cervical spine, craniovertebral junction variants, cervical ribs, and others).[1,2,4-7,9,12,14,17-20] The second most common cause included failure to obtain adequate X-rays/fluoroscopic images (i.e. inadequate number of films, poor quality films/studies, and their misinterpretation). Multiple other causes of WLS, WSS, and WSSS included; failure to use fixed reference points, operating on tumors, infection, a history of prior surgery, obesity, and osteoporosis. "Human error" was another major contributor to WLS, WSS, and WSSS and was variously attributed to; physicians/staffing fatigue, "rushing"/emergencies, failure of personnel to "speak up", failure to communicate/hierarchical operating room culture, and poor surgeon/resident/staff counting techniques.[1,2,4,5,6,8,9,12,14,17-20]

WHICH SPINAL LEVELS ARE MORE SUSCEPTIBLE TO WLS?

Most series documented a higher incidence of WLS involving the lumbar rather than the cervical

Table 1: Wrong level spine surgery.

Author Reference Year Journal	Type of study	Data	Data	Data	Conclusion
Jhawar *et al.*[8] 2007 J Neuro-surg Spine	4695 Lumbar 2649 Cervical Discs 10,203 Craniotomies	WLS Lumbar 12.8/10,000 WLS Cervical 7.6/10,000 WS Craniotomy 2.0/10,000	Reasons WLS Fatigue Rushed Emergency	Reasons WLS Unusual Anatomy Fail Verify Site/ X-Ray	Rare Events Prevention Know Risks More Intraop Imaging
Clarke *et al.*[2] 2008 Adv Surg	Avoid WSSS: Most WSSS is WSS Other: WLS (Spine)	Avoid WSSS Compare MR Check Consent Preop Check Mark	3 Step Up R- Pt R-Side R-Level Mark Site	Failures No Time Outs Do Not Speak Up XR Doc Level	Avoid WSSS Correct Label Specimens
Ammerman and Ammerman[1] 2008 J Neurosurg Spine	WSS/ WLS Survey LDisc CDisc, Crani 68% Neurosurg	4695 L. 2649 C 10,203 Crani WLS - L 4.5/10,000 WSS/WLS - C 6.8/10,000	WSS Crani 2.2/10,000	Reasons for WSS/WLS Fatigue Time Pressure Emergency	Reasons WSS/WLS Rare Anatomy Lack Confirm XR/ Fluoro REC More XR
Mody *et al.*[14] 2008 Spine	WLS-NASS and JCAHO- Guidelines Prevent WLS 415 (12%) Neurosurgeons Responded	64 (15%) of 415 had 1 WL Preop ID Corrected Before Incision But 207(50%) had WLS 1 or > Times/ Career	Rate WLS 1/3110 WLS Levels 71% L 21% C 8% Th	Permanent Disability 73 (17%) Legal Cases -Some Settled Use at Least 1 Preventive Action	Avoid WLS Better Communicate Pt/Staff Mark Site Intraop XR/Fluoro
Irace and Corona[7] 2010 J Neuro-surg Spine	Avoid WLS Micro 1L- LDisc Avoid WLS, WSS 818 Pts 2001-2005	3 Step Procedure IRACE 1-L Disc (3 X-rays)	1st XR Wire in SP (BSkin) Lateral Fluoro 2nd NOC (BSkin)	3rd: Add Fluoro Images as Needed	0 WLS 1 WLE-Wrong Level Initially Exposed-with Fluoro-Corrected
Devine *et al.*[5] 2010 Spine	Avoid WSSS 1995-2005 Joint Commission Sentinel Event Statistics Database	WSSS 2nd Most Frequent AE 455/3548 (12.8%) Studies 1990-2008	Rate WSSS Range 0.09- 4.5/10,000	No Efficacy UP No Decrease WLD or WSS	REC Intraop Imaging After Expose Review Fixed Anatomy-Check Preop Studies
Hsiang[6] 2011 Surg Neurol Int	WLS Rely on Intraop XR	Protocol Developed	Follow Protocol to Avoid WLS	WLS Results 2nd Surgery at Correct Level	Avoid Need For 2nd Surgery at Correct Level Using Protocol
Longo *et al.*[10] 2012 J Bone Joint Surg Br	WLS in Spine 12 Studies WSSS 10-L 2 L, Th, C	Higher % WLS L > C	Verify Site Fail Avoid WSSS 1/3 of Cases	No Accurate Number WSSS	No Efficacy of Site Verification Protocols
Lee *et al.*[9] 2013 Asian Spine J	Pt Safety WSSS Sign, Mark XR Program of NASS	Universal Protocol JCAHO	Incidence WSSS Not Decreased with Protocol	Prevent WSSS in OR SPEAK UP	Change OR Culture To Avoid WSSS

(Contd...)

Table 1: *(Continued).*

Author Reference Year Journal	Type of study	Data	Data	Data	Conclusion
Palumbo *et al.*[16] 2013 J Am Acad Orthop Surg	WSSS ID R-Pt R-Procedure R-Level	Protocol Cannot ID Correct Vertebral Level Surgeon Must Do This	Surgeon Must Follow Specific Pt Protocol	Ensure 3 R's R-OR R-Side R-Level	Surgeon Must Follow Protocol 3R's
Mayer *et al.*[12] 2014 Spine J	NASS Survey 173 (7.4%) Joined 72% Ortho 28% Neurosurg TL Posterior Surgery 67% WLS During Entire Career-Errors WLS 56% XR 44% Fluoro	WL Exposure (WLE/ULS) 0.32-15% Rate Reason Errors Rare Anatomy Not see Reference Points or Levels OB/Body Habitus	Reason Errors Poor Com Failed Localize After Exposure Poor Counting	Used Fluoro Th 89% Lumbar 86% Plain XR Th 54% L 58%	Resolution Needle in FJ Th 67% L 59% Needle in SP 49% L 52% REC: Time Out Better Com
Mesfin *et al.*[13] 2015 J Surg Educ	Prevent WSSS Fellows of NASS 2013-14 46 (30.3%) Surveyed 84.6% Ortho 15.4% Neurosurg	30.4% had WSSS-Only 33% Formal Training to Avoid WSSS	14 Fellows had WSSS- 79% Want Formal Training	44%(14/32) No WSSS- Not want Training	Fellowships Should Include Training to Avoid WSSS
Machin *et al.*[11] 2018 Eur Spine J	England; 978 Clinical Negligence Claims Against NHS-Ortho and Neurosurg All Spine Cases Emergency Trauma Elective Surgery All Legal Cases 2012-2017	Cost Clinical Negligence 535.5 Million Pounds 5 years Trend Higher Volume/Cost	Source Legal Cases: Poor Judgement-Timing 52.35%, Poor Interpretation Results 26.07%, Poor Outcome 19.63%	Source Cases Failure Informed Consent 8.13% WSSS or Retained Instrument 2.66%	3 Year Data-574 Claims: Iatrogenic Nerve Damage 15.8% Iatrogenic Cord damage 12.54% Infection 8.89%
Nubukpo-Gumenu *et al.*[15] 2018 World Neurosurg	Endoscopic AE L Disc-22 years 1993-2015 10,433 Pts – Avg Age 46 1189 (11.39%) 1 Intraop/Postop AE	AE RD 6.77% DT 1.91% FR 1.14%	AE 2 Level not 1-1.09% Rad 0.17% (New Deficit)	Results WLS/WI 0.08% DVT 0.04% Gauze 0.03%	WLS and Infection 0.08%
Watts *et al.*[20] 2019 Clin Spine Surg	WLS in VHA 50% Spine Surgeons Report WLS at Least ONCE in Career-Caused Harm to Pt	2000-2007 WLS-Levels 32 Cases 14 C 5 Th 13 L	69% Cause WLS Poor XR Poorly Read Poor Intraop Marking	Most Common AE: Poor XR Quality/Reading Mostly Poor Com	To Avoid WLS Get Better Image Get Better Read
Patel *et al.*[17] 2019 Spine J	Technique LS Decrease ULS/WLE and WLS 2010-2017 1988 Posterior Lumbar Procedures	Method-1st 2 Spinal Needles Before Incision Cranial/Cauda	1st XR-Needles 3 cm Lateral to Midline	2nd X-ray Confirmatory Lateral Needle in FJ	0 WLS 6 (0.3%) ULS/WLE

(Contd...)

Table 1: *(Continued).*

Author Reference Year Journal	Type of study	Data	Data	Data	Conclusion
Dablouk *et al.*[3] 2019 Br J Neurosurg	Intraop Localization Lumbar Surg 301 Patients LLam, LDisc 3 Surgeons 1 Hospital Use 3 XR Method	2015-16 Guidelines NHS OR Time 80 min LLam 67.5 min LDisc	Level WLS Surgeons ABC 8-B 4-C 1-A	ULS 13 (4.3%) 12-just 1-2 X-rays 1 XR- all 3 Only 1 with 3 level XR	0 WLS Longer OR for ULS min: 85 LLam 80 LDisc REC:3 XRAYS Increased ID and Decreased WLE/ULS
Devine *et al.*[4] 2020 Global Spine J	Update WSSS Spine Review Literature JCAHO Data Rate Lows	Universal Protocol Avoid: Wrong Pt Wrong Procedure Wrong Side	WLS Still Occurs	Surgeon--Pt Specific Protocol	ID During Surgery
Shah *et al.*[18] 2020 Cureus Lumbar	WLS LumS Spine AE Most Common: Due to Anatomic Variants	High Risk Variations TransI, Lumbar Ribs, Butterfly V	High Risk Variations Hemi-V BF- V, SD	Reasons WLS: Tumors Inf, PriorS, OB, OS 1981-2019 Review	Avoid WLS Study Anatomic Variations Better Preop Planning Review anatomy Imaging Speak to Radiology Avoid WLS and WSSS
Shah *et al.*[19] 2020 Cureus Cervical	WLS and WSSS C-2nd Most Common Anatomic Variants Risks	Anomalies CVJ Cervical Rib Hemi-V BF V.	Reasons WLS and WSS C: Tumor, Inf, Prior Surg, OB, OS		

LS: Lumbar surgery, SBNS: Society British Neurological Surgeons, LLam: Lumbar lamninectomy, LDisc: Lumbar disc, SS: Spine surgery, TL: Thoracolumbar level, NASS: North American Spine Society, Ortho: Orthopedics, Neurosurg: Neurosurgery, IRACE: Intraoperative radiograph and confirming examination, Disc: Diskectomy, 1-L: One Level, WLS: Wrong level surgery, WL: Wrong level, WSS: Wrong side surg, ID: Identify, WLE: Wrong level exposure, SP: Spinous process, NOC: Nurse oral confirmation, VHA: Veterans health administration, C: Cervical, Th: Thoracic, L: Lumbar, JCAHO: Joint Commission on Accreditation of Healthcare Organizations, DT: Dural tear, RD: Recurrent disc, FR: Facet resection, Rad: Radiculopathy, WI: Wound infection, AE: Adverse events, LSS: Lumbar spine surgery, CDisc: Cervical diskectomy, Crani: Craniotomy, WSSS: Wrong site spine surg, Intraop: Intraoperative, XR: X-rays, LumS: LumboSacral, TransI: Transitional level, V: Vertebrae, SD: Spinal dysraphism, B/F: Block/Fused, OB: Obesity, OS: Osteoporosis, PriorS: Prior Surgery, Preop: Preoperative, CVJ: Craniovertebral junction, NHS: National Health Service, UP: Universal protocol, Doc: Documentation, REC: Recommendation, BSkin: Before skin incision, R: Right, P: Patient, Com: Communication, yrs: Years, AE: Adverse events, Avg: Average, ULS: Unintended level surgery, WLE: Wrong level exposure, Fluoro: Fluoroscopy, ID: Identification

spine [Table 1].[10,14,20] Mody *et al.* (2008) observed WLS occurred in 71% of cases in the lumbar, followed by 21% in the cervical, and 8% in the thoracic spine.[14] Longo *et al.* (2012) confirmed this observation.[10] However, Watts *et al.* (2019), found WLS in 32 cases occurred more frequently in the cervical (14 cases), followed by the lumbar (13 cases), and lastly, the thoracic (5 cases) spine.[20]

AVOIDANCE OF WLS

Multiple authors offered general recommendations for avoiding WLS in the spine.[4,12,20] Mayer *et al.* (2014) suggested requiring intraoperative needles be placed either in facet joints, or spinous processes (i.e. into fixed bony structures).[12] Watts *et al.* (2019) recommended obtaining better images and requiring more astute radiographic interpretation by operating surgeons.[20] Devine *et al.* (2020) further advised repeating intraoperative imaging following the initial spinal exposure to confirm the correct level, while also comparing these studies to the preoperative images.[4]

Avoidance of WLS with Double Intraoperative X-ray Technique

Patel *et al.* (2019) recommended that spinal surgeons utilize a double intraoperative X-ray technique to avoid WLS (2010–2017; 1988 posterior lumbar cases).[17] The first X-ray involved the placement of two needles 3 cm on either side of the midline at the cranial and most caudal levels of the presumed incision. Following the initial operative exposure, the second X-ray was obtained with the confirmatory needle placed in the correct facet joint. With this technique, they observed no instances of WLS, and a reduced 6 patient (0.3%) frequency of WLE/ULS.

Avoidance of WLS Using a Tricple X-ray Method

Other authors used at least 3 intraoperative films to avoid WLS and WLE/ULS [Table 1].[3,7] Irace and Corona (2010) used a three-X-ray method to confirm the correct operative level in 818 patients undergoing lumbar laminectomy/discectomy (2001–2005).[7] The X-ray was obtained after placing a wire through the skin (before the skin incision) into the correct spinous process; the surgeon(s) had to verify its location with lateral fluoroscopy. The second step was to obtain oral verification of the correct level by a nurse in the operating room. The third step required at least one additional intraoperative fluoroscopic image for level verification; more studies could be obtained as indicated. With this 3-X-ray method, they observed no instances of WLS, and only one patient had the wrong level initially exposed (i.e. this error was recognized, and corrected with repeat fluoroscopic imaging during the index procedure). Dablouk *et al*. (2019) utilized a slightly different 3-X-ray method to localize lumbar surgical levels in 301 patents undergoing lumbar laminectomies for stenosis and disc herniations.[3] The 1st X-ray provided skin localization, the 2nd X-ray was obtained for intial "open" intraoperative localization, and the 3rd X-ray was obtained for final localization at the end of the surgery, prior to closure. They reduced WLS to 0, while WLE/ULS occurred in just 4.3% of cases.

Author's 3-4 X-ray Technique to Avoid WLS, WSS, WSSS, and WLE/ULS

Epstein's recommendation to avoid WLS, WSS, WSSS, and WLE/ULS includes a 3–4 X-ray technique, First, the patient is prepared/draped, and the first Time Out is obtained (i.e. using the 3 R's to confirm the right patient, right procedure, right level/side). Next, a sterile 18-gauge needle is percutaneously introduced into either a spinous process or an interspinous ligament; the first lateral fluoroscopic image is then interpreted/verified both by the operating surgeon and the assistant (i.e. Physician Assistant/Physician, other). This is followed by a 2nd Time Out. After initial exposure of the wound, a clamp is placed either on a spinous process or an interspinous ligament; the 2nd film is verified both by the operating surgeon and assistant. This if followed by a 3rd Time Out. Note, the patient's films on the board or TV screen must additionally be consulted to verify the correct operative site/level. Subsequently, for a disc herniation a 3rd intraoperative film is typically obtained with a Penfield elevator in the disc space. Alternatively, if a laminectomy has been performed for stenosis, the 3rd X-ray typically requires the placmeent of either a Penfield elevator or dental too at the most cephalad and caudad ends of the operative decompression (i.e. to further confirm operative levels). Notably, if fusions are being performed, there are typically many additional intraoperative fluoroscopic images taken during the course of surgery to confirm the correct level/placement of instrumentation.

INCIDENCE OF WRONG SIDE SURGERY

Clarke *et al*. (2008) cited WSS as largely attributable to the failure to use the 3 R protocol; right patient, right level, right side, plus the failure to appropriately mark the operative site preoperatively.[2] They also emphasized the need to confirm the operative site by comparing the films obtained intraoperatively with the preoperative MR studies/reports, preoperative X-rays, and operative consent.

IS THERE INTEREST IN FORMAL TRAINING TO AVOID WRONG SITE SURGERY?

Mesfin *et al*. (2015) asked spinal fellows (i.e. through NASS: North American Spine Society) to participate in a survey regarding WSSS; 46 fellows responded.[13] Fourteen of the 46 fellows had already experienced WSSS (i.e. a 30.4% incidence), and 79% of the 14 were interested in additional formal training to avoid this "error" in the future. Interestingly, for the 32 who had not yet experienced WSSS, a lesser 44% expressed interest in such training.

IMPORT OF MEDICOLEGAL SUITS AND COSTS OF WRONG SITE SURGERY

There can be significant medicolegal repercussions of WSSS.[11,14] In Mody *et al*. (2008) questionnaire, (415 neurosurgeons; 12% of the total queried), 50% of spine surgeons had at least 1 case of WLS during their careers.[14] Further, 73 (13%) patients subjected to WLS experienced permanent disabilities, resulting in legal suits, and or settlements. When Machin *et al*. (2018) reported on the impact of WSSS in England (i.e. all medicolegal spine cases between 2012 and 2017), they identified 978 spine surgery claims of "clinical negligence" brought against the National Health Service (i.e. against Orthopedists and Neurosurgeons).[11] The cost over 5 years was 535.5 million pounds; notably, the case number/costs increased over time. "Negligence" was variously attributed to; poor judgement/imaging failures (52.3%), inadequate interpretation of X-ray studies (26.07%), bad outcomes (19.63%), failure of informed consent (8.13%), and WSSS/retained instruments (2.66%). Data over 3 years resulted in 574 claims of "negligence" due to; iatrogenic nerve damage (15/8%), iatrogenic cord injury (12.54%), and infection (8.89%).

CONCLUSION

The most typical reasons for WLS, WSS, and WSSS include; unusual anatomical variations, failure to follow level/site/side verification protocols (i.e. the Universal Protocol, Time Outs, and 3 R's), and "human error". Remaining vigilant in

recognizing the different factors that contribute to WLS, WSS, and WSSS should reduce their incidence in the future.

Declaration of patient consent

Patient's consent not required as there are no patients in this study.

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Conflicts of interest

There are no conflicts of interest.

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Commentary

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The rule, measure three times, and cut once, has been an intraoperative standard for my practice. Certainly, junctional anatomy is particularly problematic, and intraoperative X-rays are often suboptimal. Use of oblique fluoroscopy and/or O-arm are helpful in morbidly obese, short necked/wide shouldered patients to prevent wrong level surgery (WLS).

How to Avoid Thoracic WLS By Placing A Coil in the "Correct" Pedicle

WLS is estimated to occur in up to10% of procedures addressing thoracic discs. Use of interventional radiology to place a coil in or near the "correct" pedicle (i.e. including the "correct" side and level of the proposed procedure) has been useful. First, the marking does not wash off like with the preoperative marking pens. Second, the fluoroscopy equipment in the radiology department is typically of better quality than the portable units in the operative suite. Importantly, this additional "procedure" is covered by most insurances and, although more expensive, is very accurate, and may avoid WLS.

Localization Issues with Minimally Invasive Surgery (MIS)

On a smaller scale, minimally invasive surgery has its own set of localization issues (i.e. as with the wanding technique to clear the interlaminar/facet junction). Residual soft tissue and/or a sub-optimally tightened retractors applied during docking may result in slippage. Here, a 1 cm arc at the skin may produce up to a 2–3 level error in the lumbar spine, and even greater level errors in the cervical spine.

Intradural Tumor Resection Utilizing Ultrasound For Site Confirmation

Lastly, for intradural lesions, a quick intraoperative ultrasound after the bony decompression allows for verification that the exposure is adequate while also allowing for level/lesion confirmation.

Conclusion

More thought and intraoperative preparation makes for safer surgery, and the avoidance of WLS, WSS, and WSSS.

Commentary

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Two spinal surgeons, one a neurosurgeon and the other an orthopedist, offer the following points regarding how to avoid wrong level (WLS), wrong side (WSS), and wrong site spinal surgery (WSSS). They both emphasized the following major points.

1. Preoperative planning
    a. Get as many plain films as needed
2. Correlate plain films and CT with the preoperative MR
    a. Especially on complex cases, those with anticipated vertebral anomalies, or with problematic physiognomy).
3. Preoperatively review the films (X-rays, MR, CT) with the radiologist/neuroradiologist to clarify the pathology and levels
    a. Particularly regarding L5-S1 anomalies
4. Do not be afraid to ask the technologist in the operating room to repeat films
    a. Do this as many times as needed where the quality and or level are not clear
5. For multilevel cervical and/or lumbar laminectomies
    a. The levels requiring decompression should be confirmed by at least 2 participants (i.e. primary surgeon and assistant surgeon/Physician Assistant)

   b. There are instances in which the decompression should be continued based on the intraoperative pathology (i.e. extent of stenosis), not just on the preoperative radiographic imaging studies
6. Penfield or Woodson should be placed in a disc space to confirm a level
   a. This especially applies to disc/far lateral disc surgery
7. There are multiple localization techniques
   a. The BEST way to localize in the lumbar spine is to put the marker in the pedicle
   b. The NEXT BEST technique is to put a Kocher on the correct facet
   c. The WORST technique is to put a marker on a spinous process
8. Cervical surgery localization (particularly posterior procedures) may be very difficult
   a. Especially with lateral mass screws at the C3 or C4 levels, or C6, C7, T1 levels
9. Thoracic Surgery Localization may be uniquely problematic
   a. Most patients are on a Jackson table
   b. Best Technique: Use AP Fluoroscopy to count ribs for level confirmation
   c. Next Best: Put a clamp on a facet
      i. Obtain a wide film to see T12 and count up
      ii. Note: some patients have anomalous rib counts
10. For ELECTIVE Thoracic Surgery
   a. Send the patient for preoperative CT localization
      i. Inject the skin and interspinous ligament with methylene blue
      ii. Obtain additional intraoperetive AP fluoroscopic confirmation of the level
   b. Before the incision put a spinal needle into the correct facet joint and take a film
   c. Open the incision and take another film to confirm/correlate the level
11. Intradural Tumor Localization Confirmation
   a. Do all the above maneuvers especially for thoracic tumor localization
   b. Before opening the dura, obtain intraoperative ultrasound to confirm the tumor location
12. Spinal Surgical Localization
   a. Multiple techniques involve reepated checks and balances
   b. Having two surgeons in the operating room where both must agree
      i. Will help confirm the correct level and correct side and site of surgery