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THE EFFECTS OF SURGEON-MADE PREOPERATIVE THREE-DIMENSIONAL MULTIPLANAR REFORMATTING ON SURGEON'S ANXIETY IN SPINAL SURGERY

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ABSTRACT

Objective: Spine surgery harbors high risks because of its complexity. This causes serious cognitive anxiety and distress during the perioperative period. We investigated the effectiveness of a surgical preoperative planning method in reducing the cognitive anxiety of the surgeon.

Materials and Methods: A training was given the study participants to create 3D MultiPlanar Reformat (MPR) images from raw DICOM files with a software. This training is named '3D MPR done by the surgeon himself/herself training (3DMPRT).' At the 6th month after the training and clinical practice, a survey was carried. The benefits of training and the cognitive anxiety status of the consultant surgeons were evaluated.

Results: Seven male spinal surgeons participated in this study. In the survey, all participants reported that they did not have the opportunity to assess preoperative spinal anatomy with radiologists and that they did not require consultation after 3DMPRT, suggesting that 3DMPRT reduced their mental distress and cognitive anxiety. After 3DMPRT, surgeons reported a change in screw insertion habits for anatomically risky pedicles during surgery.

Conclusion: 3DMPRT has a positive effect on reducing the cognitive anxiety of the surgeon and can be an alternative to costly technological devices.

Keywords: Stress, anxiety, mental distress

INTRODUCTION

Spine surgery is a risky specialty because of its complex anatomy and proximity to neurologic and vascular structures. Incorrectly positioned pedicle screws can have significant clinical implications ranging from nerve root irritation, inadequate fixation, leakage of cerebrospinal fluid, perforation of the great vessels, and damage to the spinal cord[1]. Surgical safety can be enhanced by careful preoperative surgical planning, intraoperative computer-assisted navigation, robotic surgery, and three-dimensional printed models to ensure that the implants to be placed do not damage these delicate tissues and provide high bone anchorage[1-3]. Any solution that improves the accuracy of pedicle screw placement and reduces the risk of missing pedicle cannulation will increase surgeon comfort, thereby reducing complications and improving patient outcomes. Unfortunately, it is not possible to access the above systems in every spine surgery clinic around the world. In addition, there is limited evidence to date regarding the cost-effectiveness of these systems compared to traditional pedicle screw applications[1].

The complexity and complications cause significant anxiety for the surgeon in the perioperative period[4,5]. Anxiety can be constructive (an increase in motivation, attention, and motor skills) or destructive[6-8]. Stress management is very important in this respect. One of the most helpful methods in increasing the surgeon's performance and reducing his stress is to be prepared for the surgery and to foresee what may happen during the surgery. At this point, the most ideal methods in terms of reliability in surgical planning in spine surgery today are the use of intraoperative neuromonitoring, intraoperative navigation imaging, and robotic surgery systems (INRSS)[9,10]. These radiologic aid methods are still limited, especially in centers where spinal surgery is routinely performed in developing countries, as their cost is high and their superiority over traditional pedicle screwing techniques is controversial[1]. Cognitive anxiety is thought to have a negative linear relationship with performance and a positive linear relationship with self-confidence[11]. While many publications in the literature discuss the effects of INRSS "on the patient", there is no study that focuses on the cognitive anxiety of the surgeon[1,2]. In our study, we aimed to investigate the efficacy

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of surgical planning with preoperative 3D multiplanar reformation (MPR) in reducing cognitive anxiety, which negatively affects surgeon's surgical performance, and to increase self-confidence and performance.

MATERIALS AND METHODS

Study participants were trained to create 3D MPR (multiplanar reformation, maximum intensity projection, volume rendering, and segmentation) using an imaging program [RadiAnt DICOM Viewer (software). version 2021.1. Jun 27, 2021] using raw axial computed tomography (CT) slices of the entire vertebral column obtained in DICOM format from patients scheduled for spinal deformity surgery. The duration of the training was approximately 1.5 hours. Since the participants were spine surgeons, they already knew how to open DICOM files in appropriate programs. Using the axial images in the existing DICOM file for each vertebral level to be instrumented, surgeons were asked to create reformat images as sagittal, coronal, and axial planes, as well as 3D volume renderings of the entire spine with and without costae[12]. On the axial reformat images obtained, surgeons were asked to measure the pedicle diameter, the intended length of the pedicle screw, and the intended trajectory of the screw and its angle according to the line drawn perpendicular to the posterior corpus line, according to the simple (SF) pedicle screw method[13]. Sagittal and coronal images were arranged as pedicle-wide MIP and axial images as single-voxel MPR in three columns. Hands-on practice was performed using case studies. By having each surgeon perform a 3D MPR from the DICOM file for each vertebral level prior to surgery (this concept is referred to as '3D-MPR performed by the surgeon himself (*3DMPRT*)'), screenshots of these edits are requested to be inserted into a slide presentation using Microsoft PowerPoint® software, in which the relevant spinal segment to be instrumented is identified (Figure 1 and 2), (Appendix). The prepared presentation was reviewed preoperatively by the surgical team

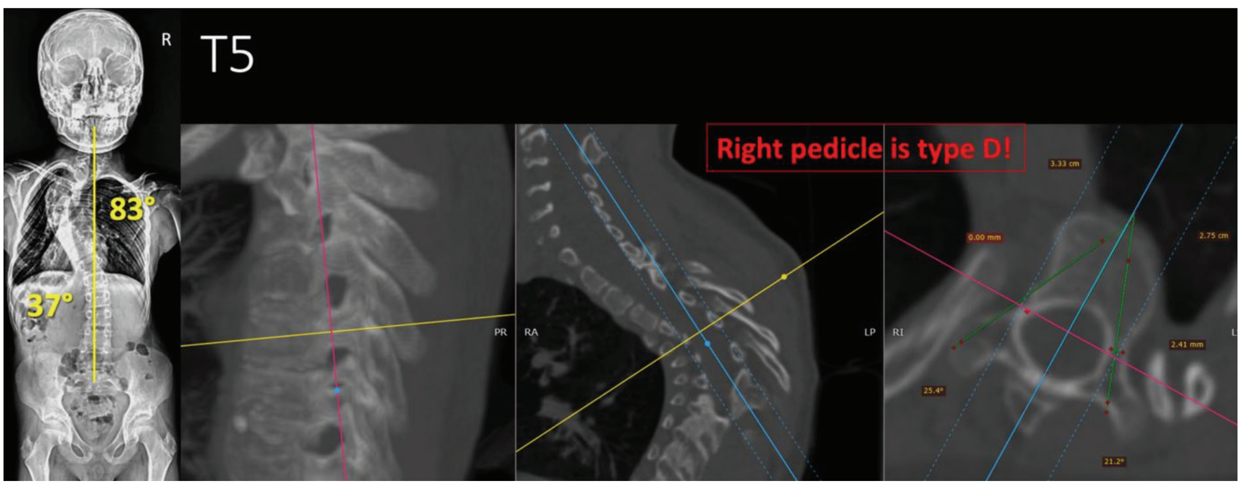

Figure 1. A typical presentation slide for the T6 thoracic vertebral level was made by the surgeon himself. Note that all lines for the orientation of the targeted pedicle screw are positioned along that axis. The right pedicle of the T5 vertebral level was omitted for instrumentation because it was too hypoplastic

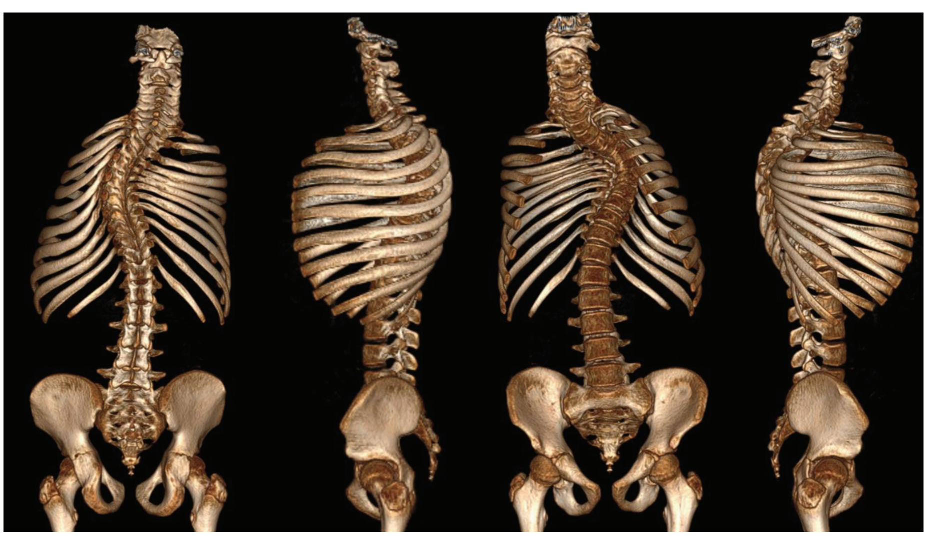

Figure 2. Three-dimensional image of the spine created by the surgeon with 3D volume rendering using axial tomography slices

and kept on the computer screen in the operating room (OR) for intraoperative guidance. Prior to instrumentation of each level, the corresponding slide presentation was inspected by the surgeons, and the screw trajectory was estimated on the case in the appropriate spatial orientation and confirmed with a C-arm scope using a marker if necessary. Screw placement was then completed under intraoperative neuromonitoring and verified with the C-arm.

At month 6 after training and clinical applications with at least 15 AIS cases, a web-based survey with thirty-two questions was conducted via Google forms sent to participants (Table 1). In addition to demographic data, the survey asked questions about the benefits of training before and after, as well as participants' levels of cognitive anxiety and psychological distress. The survey contained 18 statements on a Likert scale to which the participant responded 1 (strongly disagree) to 5 (strongly agree) depending on the statement (Table 2). Likert-type questions include a statement containing an attitude or opinion about the topic under study and options indicating the level of agreement with that statement. Surgeons' self-assessment of their level of satisfaction with 3DMPRT was rated on an analogous scale between the numbers 0 (not satisfied) and 10 (fully satisfied). Informed consent was obtained from each participant before they were asked the survey questions. All seven specialists agreed to participate in the study.

Statistical Analysis

Microsoft Excel and SPSS® Statistics v.24.0 were used for statistical analysis. For descriptive variables, analyzes of number, percentage, mean, and standard deviation were performed. Data were analyzed using non-parametric tests. Paired samples test was used for comparison of pre-and post-training results, and Mann-Whitney U test was used for descriptive characteristics and scale comparisons. A p-value of <0.05 was considered significant in all analyzes. The reliability coefficient of the Cronbach's alpha test was calculated. A Pearson correlation coefficient was calculated by sending the same questionnaire again to participants 3 weeks after the first questionnaire using the test-retest method.

Ethical Consideration

Ethical approval from the University of Health Sciences Turkey, Başakşehir Çam and Sakura City Hospital National Research Ethics Committee was obtained for the research in question (approval no.: 2022-03/94, date: 30.03.2022).

Table 1. Sections and topics of the survey

Section	Question number	Topics
Demographics	1-12	Age, sex, training, experience
3DMPRT	13-31	Likert Type scale survey
Surgeon satisfaction scale	32	Analog scale from 1 to 10

RESULTS

Demographic Features

The sample consisted of seven spine surgeons who voluntarily participated in the study and answered all questions. The average experience of the participants in spine surgery was 10 (2-26) years. Five of the surgeons were spine surgeons from orthopedics and traumatology and two of them were from neurosurgery. All participants were male. The average age of the participants was 43 (31-56) years. The average duration of specialization was 12 (2-26) years. All participants performed spine surgery in their routine practice, and the average number of spine surgery cases per month was 11 (4-30). Five (71%) of the surgeons who participated in the study had a history of spine surgery fellowship training. Three (43%) of the participants had previously worked in a center that routinely used one of the INRSS. None of the participants were actively working in a center that routinely used INRSS. Six of the participants (86%) responded that these systems could not be provided because of financial barriers, and one surgeon (14%) cited the reason for not using INRSS in the centers where he currently worked as not needing these systems.

The same questionnaire was returned to participants in the third week (test-retest method). No statistically significant difference was found between the mean of the first and the retest questionnaire and the participants' comparisons (p>0.05) (Table 3). No statistically significant difference was found when comparing participants' scale scores and subspecialization before and after training (p>0.05) (Table 4). The questionnaire was repeated 3 weeks later, and internal consistency analysis was performed. The Cronbach's alpha coefficient for the first survey was 0.688 and the Cronbach's alpha coefficient for the survey repeated at the third week was 0.744.

Participants indicated their professional satisfaction after 3DMPRT on a scale of 0 to 10 (ten being the most satisfactory number) on a "Surgeon Satisfaction Analog Score Table", was approximately 9.42/10 (minimum 7-maximum 10).

DISCUSSION

All participants in our study agreed that this 3DMPRT method could be an alternative if INRSS were not available and recommended 3DMPRT to other spine surgeon colleagues. The consulting surgeons also agreed that 3DMPRT should be included in routine spine surgery training in both orthopedics and neurosurgery.

Providing radiological images in the OR is routine for spine surgeons. The presentation prepared in this study shows the screw trajectory in the axial/sagittal and coronal planes with a calculated and prepared PowerPoint presentation for each vertebral level, just like the screws placed with an intraoperative

Table 2. The survey questions created according to the Likert-type scaling system are given in the table. The answers given by the participants to the questions were presented numerically

Questions	Strongly disagree	Disagree	No idea	Agree	Completely agree
1. I think that the use of INRSS can reduce the mental distress and cognitive anxiety that may occur in the surgical team who will perform the surgery.				4	3
2. BEFORE 3DMPRT, I did not have the opportunity to personally evaluate each patient's bony anatomy with radiologists a tomography was requested.				3	4
3. AFTER 3DMPRT, I no longer need a face-to-face evaluation with radiologists for every patient I have had a tomographic examination for bony anatomy evaluation.				2	5
4. Before 3DMPRT, I did not know how to make 3D MPR [including axial, sagittal, and coronal multiplanar reforming (MPR), maximum intensity projection (MIP), 3D volume rendering] with a Dicom file with only axial CT images.		1		3	3
5. After 3DMPRT, I learned to make 3D MPR in preoperative surgical planning by myself and it helped me to understand the bony anatomy more in detail.		1			6
6. BEFORE 3DMPRT, I believed that performing 3D MPR in preoperative surgical planning had a positive effect on postoperative patient outcomes.		1	1	3	2
7. I believe that AFTER 3DMPRT, performing 3D MPR in preoperative surgical planning has a positive effect on postoperative patient outcomes.				3	4
8. In a case where I would apply pedicle screws with equal caution to all levels before 3DMPRT, I started to consider strategic screw placement (skipping levels or choosing a smaller diameter screw, etc.) after the training by detecting the vertebrae with hypoplastic pedicles where screw application might be risky.				1	6
9. I think that preoperative planning with 3D MPR, made by the surgeon "himself", is more beneficial in terms of mastering the fine details of the bony anatomy than it is done by OTHERS.				1	6
10. I recommend 3DMPRT to my colleagues.					7
11. 3DMPRT increased my self-confidence by reducing my anxiety and mental distress during the procedures.				2	5
12. After 3DMPRT, in cases without preoperative MPR planning slides done, my anxiety and mental distress were higher (feeling insecure) compared to the cases who had the planning slides ready for the case.				4	3
13. After 3DMPRT, I feel less anxiety and mental distress, and more self-confidence in spinal deformity cases with preoperative MPR made ready on slides.				3	4
14. After 3DMPRT; In a case in which 3D MPR was prepared, "BEFORE the surgery", I think that as the surgeon who will perform the surgery, it reduces my anxiety and mental distress levels.				3	4
15. After 3DMPRT, I think that as the surgeon who will perform the surgery in a case in which 3D MPR was studied, my anxiety and mental distress levels are reduced "DURING the surgery".				2	5
16. In the patient evaluation, 3DMPRT should be included in the routine residency and spine surgery fellowship training in Orthopedics and Neurosurgery.				2	5
17. I think that 3D MPR method can be an alternative when INRSS are not available.				2	5
18. I think that 3D MPR is more cost-effective than INRSS.				1	6

INRSS: Intraoperative navigation imaging or robotic surgery systems, 3DMPRT: 3D MPR done by the surgeon himself/herself training

Table 3. First survey and re-test scale mean scores and comparisons

	n	Mean + SD	Z	*p
First survey	7	82.85±3.58	-1,687	0.092
Re-test	7	79.42±4.23		

*Paired Sample t-test
SD: Standard deviation

Table 4. Comparisons of first questionnaire and re-test scale scores with the sub-specialties

	Department	N	Mean + SD	U	*p
First survey	Orthopaedics	5	84.2±3.34	1.5	0.167
	Neurosurgery	2	79.5±0.71		
Re-test	Orthopaedics	5	79.4±4.1	4	0.696
	Neurosurgery	2	79.5±6.36		

*Mann-Whitney U test
SD: Standard deviation

navigation system such as the simultaneous O-arm™ and StealthStation™[14].

When stress and anxiety take over in situations where a high-risk task is being performed, for example, performing a surgery, it is called "performance anxiety" (PA)[15]. All the participants agreed that the currently used INRSS would reduce the mental distress and cognitive anxiety of the surgeon performing the surgery. While many publications in the literature discuss the effects of INRSS "on the patient", there is no study focusing on the surgeon's cognitive anxiety. For this reason, the method from the perspective of the surgeon, which we proposed in our study, is the first in the literature.

Occupational hazards can put physicians at risk for burnout, anxiety, depression, stress, psychologically induced sleep problems, and other types of mental health issues[16]. All participants stated that 3DMPRT increased their confidence and decreased their anxiety during surgery. According to Lang's tree-part model of anxiety responding, there are three response domains: Cognitive, behavioral, and physiological[17]. Behavioral and physiological responses can be measured with objective data such as changes in blood pressure, heart rate, skin conductance, unconscious reflexes or reactions[18]. The cognitive component of anxiety, which affects judgment and decision making, can be represented in terms of self-reports in the absence of obvious physiological and behavioral responses. Self-reports of anxiety have the potential to bias research toward overt cognitive mechanisms of anxiety[19]. However, even without physical symptoms (increased heart rate, tremors, etc.), there may be changes in the surgeon's psychological well-being, which may affect the surgical outcome[20]. While the literature on stress and anxiety in spine surgery patients is extensive, the literature on the effects of stress on the surgeon is limited[6,21-23].

Multi-detector row CT scanners can produce MPR images that allow non-axial two-dimensional images to be created with data from axial CT images[12]. Images with multiple planes can be thickened into slabs using projection techniques such as averaging, maximum and minimum intensity projection, ray summation, and volume rendering[12]. MPR images are coronal, sagittal, oblique, or curved plane images created from a plane only one voxel thick that intersects a series or "stack" of axial images. Maximum intensity projection (MIP) projects the voxel with the highest attenuation value in each view of the entire volume onto a 2D image. Before the training, only one of the seven participants knew how to create 3D MPR from raw CT images. They reported that 3DMPRT helped them understand the bony anatomy in detail. Hotton et al.[5] emphasized the importance of preoperative planning as a tool for surgical PA coping strategies. Surgeons in our study reported a reduction in surgical anxiety and psychological distress before and during surgery in 100% of cases (35% agreed, 65% fully agreed). This shows that preoperative planning with 3DMPRT can also be a useful tool. After 3DMPRT, all participants also indicated that they felt that 3DMPRT also had a positive impact on patients' postoperative outcomes. With these methods, the 3-dimensional spatial view of the bony structure of the spine can be evaluated in detail preoperatively and intraoperatively. By using this technology effectively, it can be a helpful method for the application of implants such as pedicle screws, which are used with high accuracy and reliability, especially in spinal deformity surgery. This method can be a practical alternative when expensive INRSS are not available.

Cheng et al.[24] showed that the rate of mismatched reads for abnormal CT scans was 16% and 37% were considered clinically significant. Face-to-face rounds can improve communication between radiologists and referring physicians. Its positive value is highlighted in studies as it can prevent errors and significantly impact patient safety[25,26]. All consultant surgeons in our study indicated that they did not have the opportunity to assess the bony morphology of the spine with the radiologists in every surgical candidate. This can be explained by the excessive workload in our clinical routines. After 3DMPRT, participants indicated that they no longer needed this consultation. This conclusion in our study should not be a substitute for valuable contact between radiologists and clinicians when available.

All participants indicated that they felt that 3D MPR performed by the surgeon "himself" was more beneficial in terms of mastering the fine details of bony anatomy than when performed by someone else. When the surgeon performs this assessment himself, in addition to the slides, he has more control over the dynamic three-dimensional "map" of the spine in his head without depending on the pre-set screenshots.

Participants indicated that although they attempted to place screws at each level prior to 3DMPRT, now that they can identify vertebrae with hypoplastic pedicles where screw placement could be dangerous, they tend to prefer strategic screw placement (not placing screws or choosing a smaller diameter screw, etc.).

Currently, there are not enough studies reporting on the cost of spinal navigation to make an accurate statement about its cost-effectiveness in clinical practice[27]. However, all study participants agreed that 3D MPR was much more cost-effective than INRSS. In the first section of the query, six of the participants (86%) indicated that INRSS cannot be offered in their current centers due to financial barriers. This method does not require expensive equipment with high technical infrastructure. Instead, a radiological imaging program (in our case, free software) and a computer that can perform the reconstruction process from raw data from CT are sufficient.

Once participants learned of the existence of this method, they emphasized that their anxiety level could increase if they did not have this method ready on the wall of the OR. This could be interpreted as a poor outcome due to increased apprehension, but also as an indication of how effective this method actually is. The opposite was true for participants who reported having less anxiety and psychological distress and more confidence when they had slides available.

There was an optional open-ended question like, "Does this application have any weaknesses or aspects that need improvement? Give us your suggestions" to 3DMPRT at the end of the questionnaire. One recommendation from the respondents was that automatic surveying of this system using machine learning and neural networks would be beneficial in the future in terms of a time-saving strategy. The other was that while this method helps to prepare the surgeon for the case and alleviate his anxiety, it cannot replace INRSS systems alone and is a good alternative only when these systems are not available.

Study Limitations

One of the weaknesses of our study is the absence of questions called "yes bias", which are "interspersed between the main questions and encourage the participant to be more consistent" to prevent the participant from automatically giving one positive answer after another[15,19]. However, due to the small number of participants in our study and the fact that they had previously undergone a training process, it was assumed that their responses to the questions were consistent. There is no specific test or questionnaire that has been used as a validated assessment tool for intraoperative PA[15]. Based on this aspect, we created a questionnaire by adapting the Likert scaling system for the topic we studied, a valid method in the scientific literature, and we tested its reliability in a statistical manner. Although the small number of participants in the study seems to be a negative point, the fact that qualified medical professionals are subjected to such a survey after training is a positive aspect of the study. Each participating surgical specialist works in the most developed hospitals in the country in the area where the study was conducted.

Our objective was to evaluate the efficacy of a practical technique we developed in January 2021 in our current clinical practice using Likert scaling in surgeons. This study can be considered a pilot study approved by physicians who are experts in this field. We believe that this method, if taught to more surgeons around the world, will not replace expensive systems but will provide significant benefits.

CONCLUSION

3D MPR imaging, created by the surgeon himself in the preoperative process, can be a method that has a positive effect in the application of implants such as pedicle screws used in spine surgery, with high accuracy and reliability, and can reduce the degree of perioperative cognitive anxiety and psychological stress of the surgeon. This method may be an alternative in centers where the use of an expensive INRSS is not feasible. In our study, we found that surgical planning with 3DMPRT has a positive effect on reducing cognitive anxiety, which negatively affects surgeon performance, and increases confidence and performance.

Ethics

Ethics Committee Approval: The study approval was obtained from University of Health Sciences Turkey, Başakşehir Çam and Sakura City Hospital National Research Ethics Committee (approval no.: 2022-03/94, date: 30.03.2022).

Informed Consent: Informed consent was obtained from each participant before they were asked the survey questions.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: K.A., M.Ç., A.V.Ö., B.T., M.B.B., Concept: K.A., A.D., M.Ç., A.V.Ö., B.T., M.B.B., Design: K.A., A.D., M.Ç., A.V.Ö., B.T., M.B.B., Data Collection or Processing: K.A., A.D., Analysis or Interpretation: K.A., A.D., M.Ç., A.V.Ö., B.T., M.B.B., Literature Search: K.A., A.D., Writing: K.A., A.D., M.Ç., A.V.Ö., B.T., M.B.B.

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Appendix: A PowerPoint file example of a typical preop planning case as a digital .ppt file

Link: http://glns.co/1sda0

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