Retrospective Review

The Safety of CT-Guided Epidural Steroid Injections in an Older Patient Cohort

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Background: Epidural steroid injections (ESIs) are a common method for treating lower back pain, which is one of the most prevalent health-related complaints in the adult U.S. population. Although the safety of CT-guided ESIs has been extensively studied in adults, there is limited data concerning the procedure's safety profile in an older patient population.

Objective: This retrospective study analyzed safety data among a single-center cohort of patients > 65 years-old who received one or more CT-guided interlaminar ESIs from 2012 to 2015.

Study Design: An Institutional Review Board (IRB)-approved retrospective chart review.

Setting: University hospital center.

Methods: A total of 688 CT-guided ESI procedures were evaluated and a linear regression analysis was conducted to examine the relationship between dose length product (DLP), body mass index (BMI), procedure duration, and kVp/mA settings. Further analysis was performed on a sample of long procedure time, average-DLP and high-DLP procedures.

Results: Average age was 75.77 years, with 44% having a BMI > 30. The mean DLP was 55.58 mGy x cm and the mean procedure duration was 5.94 minutes. All procedures were technically successful and no complications were observed during or after any of the procedures, including at one-month follow-up office visits. The kVp and mA settings were the strongest predictors of DLP, followed by procedure time. The high-DLP cases had a greater number of needle placement series, more intervertebral disc spaces included in each planning series and higher machine settings (kVp 120; mA 87.5) than the average-DLP cases (kVp 100; mA 49.9).

Limitations: This study is limited by its retrospective design.

Conclusion: CT-guided interlaminar ESIs can be performed safely, with low procedure times, relatively low DLP's and without complications in an older patient population.

Key words: Epidural steroid injection, interlaminar approach, CT-guidance, older adults, back pain, lumbar spine, thoracic spine, cervical spine, dose length product, radiation exposure

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Epidural steroid injections (ESIs) are a common method for treating lower back pain, which is one of the most prevalent health-related complaints in the adult U.S. population (1,2). The estimated annual incidence for this condition is increasing among the elderly, with 30% of Americans 65 years and older reporting symptoms of lower back pain in 2013 (3). In light of this trend and the fact that there are increased risks with surgery in the elderly compared to the general population (4-8), there has been an increase in the number of older patients who are being referred for ESIs for treatment of refractory lower back pain (9-10).

Fluoroscopic guidance for ESIs has been the standard of care for decades. However, computed tomography (CT) guidance has been increasingly adopted for use in ESIs in recent years (11-14). For maximal safety and efficacy, it is essential to accurately localize the needle tip within the epidural space and avoid radicular arteries (15-17). CT guidance for an interlaminar injection allows visualization of soft tissues and precise millimeter measurements while avoiding the radicular arteries within the foramina (13,18). Additionally, CT-guided interlaminar ESIs allow for localization of the epidural space with air contrast, which eliminates the risk of allergic reactions in contrast-sensitive patients. Previous reports have shown that the radiation dose with CT-guided ESIs using air contrast is similar to the typical effective dose from continuous fluoroscopic guidance (0.43 – 1.25 mSv for 1 – 3 minutes of guidance) (12,19).

The theoretical downsides of CT-guided procedures of potentially prolonged procedure time and high radiation dose have been mentioned previously (19). CT-guided spine pain procedures have been done quickly and with lower radiation doses than diagnostic CT scans (15) and perhaps with lower radiation exposure and procedure time than fluoroscopically guided procedures (16).

Although the safety of CT-guided ESIs has been extensively studied in adults, there is limited data concerning the procedure's safety profile in an older patient population (9,20-21). The purpose of this study is to analyze safety data among a single-center cohort of patients aged 65 years and older who received one or more CT-guided interlaminar ESIs from 2012 to 2015 for treatment of lower back pain, cervical spine pain, or thoracic spine pain. To this end, the data were expected to show that CT-guided ESIs can be conducted with short procedure times, low radiation exposures, and without complications, even in an older patient population.

Methods

This retrospective cohort analysis was performed according to HIPAA regulations and was approved by the Institutional Review Board. A consecutive cohort was retrospectively identified from a search of the electronic medical record. The search included all interlaminar CT-guided ESIs performed in adults aged 65 years and older at a single institution from 2012 to 2015. Patients were seen in consultation prior to the procedure to go over potential risks and to obtain informed consent. Patients were seen one month after the procedure for follow-up.

For each procedure, patients were placed in a prone or semi-prone position on the CT gantry and their back was then sterilely marked, prepped, and draped after a scout and axial planning images were obtained. Each patient underwent several helical images through the target spinal level. All epidural injections were performed with intermittent scanning mode using a dorsal interlaminar approach. Air contrast, or rarely iodinated contrast agent, was injected in order to verify the needle tip location within the epidural space. Any potential complications were recorded and reported according to Society of Interventional Radiology guidelines (22).

All of the procedures were reviewed on PACS to ensure that they were correctly categorized. Demographic (age, gender) data and body mass index (BMI) information was obtained from the electronic medical record. The procedure data collected included the spine region treated (lumbar, thoracic, or cervical), procedure duration, dose length product (DLP), and the mA and kVp. Procedure duration was measured by using the PACS time stamp on the scout image and the PACS time stamp on the last axial image in the last series of the procedure. The values for procedure duration were then obtained by subtracting the "time of scout" from the "time of last axial" in order to obtain the exact time period of each procedure included in the study. The CT dose report produced by the CT machine was reviewed on PACS and the DLP was documented. Additionally, data were recorded on which procedures utilized air contrast versus iodinated contrast agent and whether or not sedation was used.

The Statistical Package for the Social Sciences (Version 22.0, IBM SPSS Statistics) was used to conduct a linear regression analysis for examining the relationship between DLP and the potential predictors procedure time and BMI. This was done for all of the procedures included in the study that had BMI data available. For outlier patients with high DLPs (defined as > 1.5 SD above the average), a separate linear regression analysis was done in order to assess the impact of procedure time, BMI, and kVp and mA settings from the last axial scan on DLP. This was done in order to quantify the extent that the high radiation exposure seen in these patients was caused by obesity, an excessively long procedure time, or human error (CT scanner settings inappropriately high mA and/or kVp level).

Further analysis of the long procedure time cases was conducted by recording the total number of needle placement series and wait times (defined as the time interval from the beginning of the planning series to the first needle placement series) for the 12 outliers with the greatest procedure durations. A random sample of 15 cases with an average DLP (+/- one unit from the study's mean DLP of 55.58) was taken in order to measure the number of intervertebral disc spaces in the planning series, the total number of needle placement series, and the kVp and mA settings of the last axial image. This same data were collected for a sample of 15 high-DLP outlier cases in order to compare the 2 groups and ascertain the impact of these variables on influencing DLP.

Results

A total of 466 patients underwent 688 CT-guided interlaminar ESI procedures. There were 454 (66%) women and 234 (34%) men. The average patient age was 75.77 years (range 65 – 96, SD +/- 7.61). There were a total of 666 (97%) lumbar ESIs performed. Seventeen (2.47%) cervical ESIs and 5 (0.74%) thoracic ESIs were included in the cohort. All procedures were technically successful and no complications were observed during or after any of the procedures, including at one month follow-up office visits. A total of 646 procedures were performed utilizing air contrast (95%) and 43 with iodinated contrast (6.7%). Of the procedures that were performed with iodinated contrast agent, 24 were lumbar ESIs and 15 were cervical ESIs. Three procedures utilized conscious sedation (2 mg versed, 50 mcg fentanyl), all of them lumbar ESIs. The average procedure duration for all procedures included in the study was 5.94 minutes (range 1.47 – 20.6 minutes, SD +/- 2.71 minutes). The average DLP was 55.58 mGy x cm (median 43.93, range 20.86 – 290.79, SD +/- 35.60). BMI data was available for 548 of the patients, with 241 of those patients (44%) being defined as obese. The average BMI was 28.86 (range 12.29 – 55.64, SD +/- 6.156).

Table 1 summarizes the linear regression analysis results for the 548 procedures included in the study that had BMI data available. The predictor variables procedure time and BMI were positively and significantly correlated with DLP. Procedure time was found to be a significant predictor of DLP (b = 6.449, t [545] = 15.4, *P* < .05), with a 6.45-unit increase in DLP expected for each minute increase in procedure time. Similarly, BMI was determined to be a significant predictor of DLP (b = 2.321, t [545] = 12.2, *P* < 0.5), with a 2.32-unit increase in DLP expected for every unit increase in BMI. Procedure time was a stronger predictor variable than BMI (Beta = 0.418, t [545] = 15.4, *P* < .05).

Table 1. *Linear regression analysis coefficients for all procedures (N = 548).*

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-51.340	5.997		-8.560	0.000
Procedure Time (minutes)	6.449	0.418	0.494	15.411	0.000
BMI	2.321	0.190	0.391	12.199	0.000

Table 2. *Linear regression analysis coefficients for all procedures with DLP values within 1.5 standard deviations from the mean (N=508).*

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-23.040	3.832		-6.013	0.000
BMI	1.615	0.120	0.438	13.509	0.000
Procedure Time (minutes)	4.246	0.273	0.505	15.563	0.000

Table 2 summarizes the linear regression results for the 508 procedures included in the initial analysis with BMI data available that also had DLPs within 1.5 SDs from the mean (<112.4 mGy x cm). Similar to the results displayed in Table 3, procedure time and BMI were positively and significantly correlated with DLP. With the high-DLP outliers removed, both procedure time (Beta = 0.505, t [505] = 15.56, *P* < .05) and BMI (Beta = 0.438, t [505] = 13.51, *P* <.05) were found to be more significant predictor variables, with procedure time having a slightly larger effect on DLP than BMI.

Table 4 displays the correlation coefficients for the high-DLP outlier procedures, demonstrating positive linear relationships between the outcome variable DLP and the predictor variables procedure time, BMI, kVp of last axial image, and mA of last axial image. Table 5 summarizes the linear regression analysis for the 40 patients who had DLP scores greater than 1.5 SDs from the average (>112.4 mGy x cm). The predictor variables procedure time, BMI, kVp of last axial, and mA of last axial all were positively and significantly correlated with DLP. For this group of high-DLP outliers, every minute increase in procedure time was associated with a 4.175-unit increase in DLP (b= 4.175, t [35] = 3.125, *P* < .05). BMI was found to be a slightly weaker predic-

Table 3. *Pearson correlation coefficients for all procedures demonstrating positive linear relationships between the outcome variable DLP and predictor variables Procedure Time and BMI (N=548).*

	DLP (mGy x cm)	Procedure Time (minutes)	BMI
DLP (mGy x cm)	1.000	.548	.459
Procedure Time (minutes)	.548	1.000	.138
BMI	.459	.138	1.000

Table 4. *Pearson correlation coefficients for high-DLP outlier procedures (N=40).*

	DLP (mGy x cm)	BMI	Procedure Time (minutes)	kVp of last axial
DLP (mGy x cm)	1.000	0.297	0.212	.447
BMI	0.297	1.000	0.059	-.148
Procedure Time (minutes)	0.212	0.059	1.000	-.378
kVp of last axial	0.447	-0.148	-.378	1.000
mA of last axial	0.376	0.307	.293	-.272

Table 5. *Linear regression analysis coefficients for high-DLP outlier procedures (N=40).*

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-281.087	60.906		-4.615	0.000
BMI	1.384	0.572	0.264	2.421	0.021
Procedure Time (minutes)	4.175	1.336	0.358	3.125	0.004
kVp of last axial	2.896	0.454	0.727	6.375	0.000
mA of last axial	0.395	0.117	0.388	3.381	0.002

tor (b= 1.384, t [35] = 2.421, $P < .05$), with a 1.384-unit increase in DLP being predicted for every unit increase in BMI. The kVp setting of the last axial image was also found to be a strong, positive predictor (b = 2.896, t [35] = 6.375, $P < .05$), with each unit increase in kVp being associated with a 2.896-unit increase in DLP. Not surprisingly, a slightly weaker predictive relationship was found between the mA of the last axial image and DLP (b= 0.395, t [35] = 3.381, $P < .05$), with a 0.395 increase in DLP expected for every unit increase in mA. Based on the standardized Beta coefficients, it can be surmised that the kVp settings of the last axial had the strongest predictive effect on DLP (Beta = 0.727, t [35] = 6.375, $P < .05$), followed by the mA settings of the last axial (Beta = 0.388, t [35] = 3.381, $P < .05$) and then procedure time (Beta = 0.358, t [35] = 3.125, $P < .05$).

The further analysis conducted on the long procedure time outliers demonstrates how most of these cases (58.3%) had wait times exceeding 5 minutes and also required at least 5 needle placement series to localize the epidural space (Table 6). This finding highlights the significant role that these variables likely played in contributing to a positive, linear relationship between the predictor variable procedure time and the outcome variable DLP.

The average number of needle placement series for the high-DLP sample cases was 4.3, compared to 2.3 for the average-DLP sample cases (Table 7, Table 8). This finding supports the theory that more technically difficult cases with an increased number of needle placement series are associated with a higher level of radiation exposure. Similarly, the average number of intervertebral disc spaces in each case's planning series was 3.33 for the high-DLP sample cases compared to 2.93 for the average-DLP sample cases.

The 15 average-DLP sample cases had a mean kVp of 100 and a mean mA of 49.9 for the last axial images (Table 8). These technique settings are lower than the mean kVp of 120 and mean mA of 87.5 for the 40 high-DLP outlier cases. This finding lends additional support to the linear regression analysis results outlined in Table 5, which demonstrated that kVp and mA settings were the strongest positive predictors of DLP. In other words, the greatest impact on lowering radiation dose will likely come from decreasing the kVp and mA settings of the CT-scanner.

Discussion

The study cohort's average age of 75.77 years was significantly higher than the average age of patient cohorts in prior studies that examined CT-guided ESIs (12,15-17). In this way, these results are specific for an older patient population and accordingly demonstrate how ESIs are safe, short duration procedures that can be accomplished with low radiation exposure in elderly adults. The average DLP value of 55.58 +/-35.60 mGy x cm is significantly lower than average DLP values reported previously in adult populations (15-16). The

Table 6. *Further analysis of twelve long procedure time outlier cases.*

Case number	Procedure Time (minutes)	DLP (mGy x cm)	Wait Time (time interval between planning series and first needle placement series)	Number of needle placement series	Comments
1	20.6	79.12	> 5 minutes	7	Iodine agent used; technically difficult procedure
2	17.2	162.97	< 5 minutes	9	Iodine agent used; technically difficult procedure
3	17.1	102.07	< 5 minutes	5	
4	15.4	184.18	< 5 minutes	8	Iodine agent used; technically difficult procedure
5	15.3	84.17	> 5 minutes	5	
6	15.0	93.88	> 5 minutes	5	
7	14.9	111.9	> 5 minutes	5	
8	14.7	74.14	> 5 minutes	5	
9	14.6	203.05	> 5 minutes	5	
10	14.5	207.49	> 5 minutes	6	Iodine agent used; technically difficult procedure
11	14.4	100.85	< 5 minutes	6	Iodine agent used; technically difficult procedure
12	14.4	133.85	> 5 minutes	5	

lower average DLP reflects increased experience and incorporation of suggestions from the growing body of literature on the subject. The main changes implemented were lowering the kVp and mAs and shortening the initial planning series to a single target level rather than imaging 3 or more levels as had been the local practice.

The average procedure time of 5.9 minutes was lower than previous reports (12,15). The short procedure durations in this study reflect benefits conferred from accumulated experience of the team and attention to total patient "time on the table." These time reductions are similarly associated with a production of lower average DLP, since lower mean procedure times are reported to be associated with a lower mean DLP and reduced radiation exposure (23).

Since 44% of the procedures included in this study were conducted on individuals with a BMI > 30, the results also suggest that ESIs can be safe in an older patient population with a significant percentage of obese individuals. Additionally, the linear regression results imply that procedure time had a slightly greater positive predictive effect on DLP than did BMI (Table 2, Table 3).

Table 7. *Further analysis of fifteen high-DLP outlier cases.*

Case number	DLP (mGy x cm)	Number of intervertebral disc spaces in planning series	Number of needle placement series
1	113.29	3	5
2	113.32	4	6
3	114.59	3	5
4	115.83	4	4
5	117.75	3	1
6	117.83	4	3
7	118.8	4	6
8	120.75	4	3
9	122.56	3	2
10	123.12	4	4
11	125.18	2	5
12	125.88	2	4
13	128.07	4	5
14	129.94	3	6
15	133.85	3	5

Table 8. *Further analysis of fifteen average-DLP cases (within one unit of the study's mean DLP of 55.58 mGy x cm).*

Case number	DLP (mGy x cm)	kVp of last axial	mA of last axial	Number of intervertebral disc spaces in planning series	Number of needle placement series
1	55.03	100	65	3	1
2	55.07	100	60	3	2
3	55.07	100	60	3	2
4	55.07	100	60	3	2
5	55.07	100	45	2	3
6	55.13	100	60	4	1
7	55.18	100	55	3	2
8	55.25	100	40	3	4
9	56.13	100	40	3	3
10	56.13	100	40	2	4
11	56.17	100	80	2	1
12	56.34	100	40	2	2
13	56.44	100	40	3	2
14	56.61	100	45	4	3
15	56.73	100	55	2	1

The additional analysis conducted on the study's longest procedure time cases (Table 6) highlights the importance of minimizing the number of needle placement series to keep procedures short and also brings up the issue of wait times, or the time interval between the planning series and the first needle placement series. For unknown reasons, 8 of the 12 long procedure time outliers included in Table 6 had long wait times. It may be that the longest cases were the most technically demanding that required the most attempts at accessing the epidural space. The long wait times may be due to prolonged analysis of the initial planning series by the procedure team.

Similarly, the data presented in Table 7 and Table 8 lend additional support to the notion that there are ways to reduce procedure time and lower radiation dose. The data show that the high-DLP sample cases had a higher average number of needle placement series and also a higher average number of intervertebral disc spaces in each planning series than did the average-DLP sample cases. A greater amount of degenerative stenosis in an older population may create more technically demanding procedures. Limiting the number of series to the minimum required for safely placing the needle in the epidural space has the greatest effect on reducing the overall DLP. When anticipating a difficult procedure, we tended to lengthen the planning series in anticipation of more complex patient anatomy. Minimizing this series to a single target level by using pre-procedure imaging would reduce radiation dose as the planning series typically accounts for 30% – 60% of the total dose from the procedure (16).

The results from the separate linear regression analysis conducted on this study's high-DLP outliers reveal that the kVp and mA settings of the last axial likely exerted a greater positive predictive effect on DLP than either procedure time or BMI (Table 5). Human error with the kVp and mA settings on the CT scanner had a stronger influence on the high radiation exposures seen in these patients than either procedure time or BMI. Prior studies that examined CT-guided ESIs used 120 kVp as the standard setting for all patients (12,15-17). In regard to tube current, Chang et al (15) and Chang et al (12) used 50 mA as the standard for all patients. In comparison, 26 of our high-DLP subgroup patients had mA settings on their last axial image > 80 mA, with 14 of those procedures being > 100 mA. Reduction in tube current has already been demonstrated to have a substantial impact on lowering radiation dose and recent research has suggested new techniques such as the incorporation of attenuation-based tube current modulation and noise-reduction algorithms to help achieve this goal (16,24-25). This study lends additional support to this conclusion. However, since kVp is the strongest positive predictor of DLP (Table 5), radiation dose reduction efforts should primarily focus on confirming appropriate kVp settings for procedures in order to have the greatest impact on lowering DLP.

The study's high-DLP outliers had a mean kVp of 120 and a mean mA of 87.5 for the last axial settings while the average-DLP sample cases in Table 8 had a mean kVp of 100 and a mean mA of 49.9. Considering that all the procedures were technically successful and the average BMI of the population, the lower settings in the average-DLP cases suggest that ESIs can be performed accurately at lower kVp and mA settings.

Conclusion

This study's results suggest that CT-guided ESIs can be conducted safely, with short procedure times, relatively low DLPs, and without complications in an older patient population. The analysis of the outlier cases with longer procedure times and higher radiation exposures indicate that evaluating multiple intervertebral disc levels and requiring multiple needle placement series may have been responsible for these observed results. To this end, these findings underscore the importance of minimizing the length of the planning series and the number of needle placements in order to maximize patient safety.

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