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Radiation exposure during basivertebral nerve radiofrequency ablations

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ABSTRACT

Background: Basivertebral nerve radiofrequency ablations (BVNRFA) is a relatively new procedure that has demonstrated positive effects to treat chronic low back pain. Fluoroscopy guidance is utilized to access the vertebral body via the pedicle and confirm the correct location of the probe for ablation. Radiation exposure during this procedure has not been previously reported.

Objective: The purpose of this study was to evaluate the average fluoroscopic time and radiation exposure during BVNRFA.

Methods: Patients treated with BVNRFA that had failed conservative treatment, with primarily midline back pain, and corroborating Modic type I or Modic type II changes on MRI at a tertiary academic spine center were retrospectively analyzed. Chart review was conducted to obtain patient demographics, fluoroscopic time and radiation exposure, involvement of trainees, and vertebral levels treated. Average fluoroscopic and radiation exposure was calculated.

Results: A total of 55 patients were included in this study. The average fluoroscopic time was 152.5 s (±84.3 s). The average cumulative dose was 70.3 mGy (±53.0 mGy) and the average dose area product was 7.9 mGy·cm2 (±5.2 mGy·cm2).

Conclusions: Our study demonstrated that the average fluoroscopic time during BVNRFA to be about 2 and a half minutes.

1. Introduction

Basivertebral nerve radiofrequency ablation (BVNRFA) is a relatively new procedure utilized to treat vertebrogenic back pain. BVNRFA has been demonstrated to be an effective procedure in providing long term pain relief [1]. In Conger et al.'s meta-analysis of 12 studies, they found that BVNRFA led to significantly improved pain, disability and function up to 2 years [2].

BVNRFA requires fluoroscopic guidance to access the vertebral body via the pedicle and decrease the risk of spinal nerve injuries. Fluoroscopy guidance also ensures that appropriate anatomical placement of the probe is achieved to provide ablation of the basivertebral nerve (BVN).

Cumulative radiation exposure and dose to patients, physicians, and staff have been associated with negative long-term health outcomes [3–8] specifically cataracts [9] and cancer [10–12]. Protective equipment is utilized during the procedure to decrease and minimize these risks [13–16]. Decreasing fluoroscopic time during procedure use also decreases the overall radiation risk [17]. Patient factors such as BMI [18] and procedural factors such as presence of a trainee [19] have also been shown to impact radiation exposure during spine procedures.

To our knowledge, fluoroscopy time and radiation dose have not been reported for patients undergoing BVNRFA. The purpose of this study was to report average fluoroscopy time and radiation dose for patients undergoing BVNRFA and assess the impact of patient and procedural factors on radiation exposure.

2. Methods

This retrospective study was approved by the Institutional Review Board at the University of Rochester. Consecutive adult patients undergoing BVNRFA between May 01, 2023 and September 30, 2024 were included in this study. All procedures were performed by the senior author (AA) who completed an accredited pain fellowship as well as additional training from the manufacturer of BVNRFA equipment. BVNRFA was indicated for patients if they had primarily midline low back pain without radicular symptoms and corroborating Modic type I or type II changes noted on MRI [20]. BVNRFA was performed as

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described in the literature [21]. In our study, all patients were treated with 7-min ablations. The months of the provider's practice that each BVN RFA was performed was broken up into 5 3-month time period stages. Of note, there were two months within the 17-month time frame where no BVNRFA was performed.

2.1. Statistical analysis

Mean and standard deviation were calculated for continuous variables. Number and percent were calculated for categorial variables. BMI was classified as normal (BMI <25.0 kg/m^2), overweight (BMI = 25.0–29.9 kg/m^2), and obese (BMI ≥30.0 kg/m^2). A statistical software package (SPSS) was used to analyze the data. Univariate analysis was conducted to assess the impact of BMI classifications, levels treated, S1 involvement, stages in practice, and the presence of a trainee. Finally, controlling for all other variables, a multivariate linear regression analysis was conducted to assess the impact of age, sex, BMI (as a continuous value), involvement of a trainee, stages in practice, levels performed, and involvement of S1 for both fluoroscopy time and cumulative dose. The level of significance was set at 0.05.

3. Results

A total of 55 patients underwent BVNRFA during the inclusion time period. Demographic data is presented in Table 1. The average procedure length was 67.6 min (±25.8 min) and the fluoroscopic time of all the procedures was 152.5 s (±84.3 s). The average fluoroscopic exposure time per level performed was 50.7 s (±19.1 s). The average cumulative dose was 70.3 mGy (±53.0 mGy) and the average dose area product was 7.9 mGy·cm2 (±5.2 mGy·cm2). Univariate analyses evaluating the impact of the number of levels treated, presence of a trainee, patient BMI, stages in practice, and the inclusion of S1 on the average fluoroscopic time (seconds) and average cumulative radiation dose (mGy) are reported in Tables 2 and 3, respectively.

Regression analysis of factors correlating with fluoroscopy time had a R^2 of 0.66. Compared to performing 4 levels, performing 1 level ($\beta = -149.4$, $p = 0.002$), 2 levels ($\beta = -106.4$, $p < 0.001$), and 3 levels BVN RFA ($\beta = -82.1$, $p = 0.04$) were significantly correlated with less fluoroscopy time. Compared to the fluoroscopy time in the first stage of practice, there was a significant difference in fluoroscopy time at the 2nd ($\beta = -78$, $p = 0.02$), 3rd ($\beta = -104.8$, $p = 0.001$), and 5th stage of practice ($\beta = -109.9$, $p < 0.001$). Additional multivariate data is presented in Table 4.

Multivariate regression analysis of factors correlating with cumulative radiation dose exposure had a R^2 of 0.58. In a multivariate regression analysis controlling all other variables (age, sex, BMI, levels performed, S1 involvement, stage in career, or trainee involvement), increased BMI ($\beta = 5.15$, $p < 0.001$) was significantly correlated with increased cumulative radiation dose exposure. Involvement of S1 was correlated with greater radiation exposure compared to no involvement of S1 ($\beta = 38.5$, $p = 0.03$). Additional multivariate data is presented in Table 5.

Table 1
Patient and procedure demographics.

Variable	Mean/N	Standard Deviation/%
Age	65.2	13.9
Sex		
Female	28	51 %
Male	27	49 %
BMI	30.34	6.0
Normal	10	18.2 %
Overweight	23	41.8 %
Obese	22	40.0 %
Race		
White	52	95 %
Black	2	4 %
Not Disclosed	1	2 %
Area Deprivation Index	58	18.0
Number of Levels	3	1
Involvement of Trainee	32	58 %
S1 Involvement		
Yes	43	78 %
No	12	22 %
Procedure Time (minutes)	67.44	25.6
Fluoroscopic Time (seconds)	150.2	82.8
Dose Area Product (Gy·cm$^{2)}$	7.8	5.1
Cumulative Dose (mGy)	68.6	51.5

Table 2
Univariate analysis of the impact of patient and procedural demographics on fluoroscopy time.

Variable	Mean Fluoroscopy Time (Standard Deviation)	P value
Trainee Involvement		
Yes	151.1 (85.6)	0.924
No	148.8 (78.4)	
BMI Classifications		
Normal	137.9 (53.8)	0.379
Overweight	168.7 (94.8)	
Obese	135.8 (74.9)	
Number of Levels		
1	52 (5)	<0.001
2	97.4 (37.4)	
3	125.3 (9.5)	
4	207.2 (80.3)	
Involvement of S1		
Yes	164.9 (86.0)	0.009
No	92.5 (23.8)	
Stages of Practice		
1st	264.7 (103.2)	<0.001
2nd	153.9 (56.6)	
3rd	117.2 (55.9)	
4th	147.2 (76.7)	
5th	123.1 (54.0)	

Table 3
Univariate analysis of the impact of patient and procedural demographics on cumulative radiation dose.

Variable	Mean Cumulative Radiation Dose mGy (Standard Deviation)	P value
Trainee Involvement		
Yes	61.7 (42.6)	0.24
No	78.7 (60.9)	
BMI Classifications		
Normal	47.3 (23.8)	<0.001
Overweight	62.1 (34.2)	
Obese	84.7 (67.8)	
Number of Levels		
1	19.1 (4.7)	0.55
2	62.4 (60.8)	
3	47.3 (5.7)	
4	80.4 (42.8)	
Involvement of S1		
Yes	76.0 (54.9)	0.04
No	39.7 (14.1)	
Stages of Practice		
1st	88.0 (40.0)	0.19
2nd	99.8 (77.2)	
3rd	69.1 (55.9)	
4th	55.8 (23.1)	
5th	57.3 (47.9)	

4. Discussion

This study reported the average fluoroscopic time for BVNRFA to be about two and half minutes. The average effective dose was 71.9 mGy.

The radiation exposure during fluoroscopic interventional spine procedures are risks for future complications for patients and the medical team [3–6,8]. Radiation exposure varies based on the spinal

Table 4
Multivariate analysis of the impact of patient and procedural demographics on fluoroscopy time.

Variable	Coefficient (β)	P value
Age	−0.04	0.583
BMI Classifications	1.97	0.17
Sex		
Female	Reference	
Male	−8.4	0.6
Trainee Involvement		
No	Reference	
Yes	3.2	0.87
Number of Levels		
1	−149.4	0.002
2	−106.4	<0.001
3	−82.1	0.004
4	Reference	
Involvement of S1		
No	Reference	
Yes	4.3	0.86
Stages of Practice		
1st		
2nd	−78	0.02
3rd	−104.8	0.001
4th	−60.7	0.052
5th	−109.9	<0.001

Table 5
Multivariate analysis of the impact of patient and procedural demographics on cumulative radiation dose.

Variable	Coefficient (β)	P value
Age	−0.25	0.58
BMI Classifications	5.15	<0.001
Sex		
Female	Reference	
Male	−20.7	0.07
Trainee Involvement		
No	Reference	
Yes	−0.2	0.99
Number of Levels		
1	−40.2	0.19
2	−20.2	0.17
3	−42.6	0.1
4	Reference	
Involvement of S1		
No	Reference	
Yes	38.5	0.03
Stages of Practice		
1st	Reference	
2nd	12.8	0.57
3rd	−14.3	0.49
4th	−18.1	0.39
5th	−25.8	0.16

procedures. For example, Cohen et al. found that the average fluoroscopy time for lumbar facet injections was shown to be 16.5 s per site and 24.3 s per lumbar transforaminal epidural steroid injection site [22].

According to the US Nuclear regulatory commission the average American is exposed to 6.20 mGy of radiation annually [23]. Taken together, the median BVNRFA is equivalent to 8.5 years of average radiation exposure for Americans and is equivalent to roughly 7.6 chest CTs [23]. Crawley and Rogers originally described radiation exposure for common fluoroscopic orthopaedic surgeries to establish reference doses for radiological procedures to optimize patient care. Their study reported the median DAP for hip and spine procedures to be approximately 10 Gy $\cdot$ cm^2 [24]. Cohen et al. proposed reference values for radiation dose for fluoroscopically guided lumbar procedures as 13 mGy for transforaminal/intralaminar injections, 7 mGy for RFA, and 4 mGy for medial branch blocks [22]. The DAP reported by Crawley and Rogers's study is similar the BVNRFA radiation exposure reported by this study. These findings suggest BVNRFA radiation exposure is on the order of orthopaedic surgeries and less similar to commonly performed interventional pain procedures for the lumbar spine.

The International Atomic Energy Agency (IAEA) has developed a "dose conversion coefficient" which can be used in combination with quotient of the effective dose and dose-area product to estimate risk of cancer. The IAEA reports the dose conversion coefficient for fluoroscopically-guided *diagnostic* lumbar spine procedures is 0.21. According to the data published in this study and the IAEA, an average BVNRFA could theoretically increase risk of cancer by 1.9 % [25]. It is important to consider the age of the patient as an important factor in understanding this radiation risk as the risk of developing cancer following radiation exposure decreases as age, at time of exposure, increases.

Our study did not find a significant impact of BMI on fluoroscopic time. Although there are no BVNRFA studies to directly compare to, this finding is similar to findings for patients undergoing sacroiliac joint injections [26], lumbar medial branch radiofrequency ablations [19] and cervical interlaminar injections [27]. This differs from published work regarding lumbar transforaminal epidural steroid injection [18]. Our study found that increased radiation dose was associated with increased BMI. Our study also found no significant difference between cases performed with a trainee for radiation exposure time or cumulative dose. This is consistent with McCormick et al.'s study in the cervical spine [27] but differs from Wagner et al.'s study of lumbar radiofrequency ablations [19].

Unsurprisingly, patients who underwent BVNRFA of more levels had statistically significant greater fluoroscopic exposure times. S1 involvement was also associated with significantly greater radiation exposure. Although a similar transpedicular access technique is used access the S1 pedicle, patient anatomy dictates how the procedure is performed. There is variability in iliac crest height in respect to S1 pedicle. The initial obliqued trajectory can be limited in "deeper" sacrums where an obliqued view can be obscured due to high iliac crests. For this reason, additional radiation is used for initial image optimization and pedicle docking. This is not an issue in the lumbar spine where the osseous structures are not in the way with an oblique transpedicular view. Unsurprisingly, there was significantly longer fluoroscopy times during the first few months of performing BVNRFA compared to later in the year. Though not controlled for BMI or levels performed, the average fluoroscopy times of the later months were less than half the average times of the earlier month a BVNRFA was performed. This finding should be taken into consideration when interpreting the relatively large radiation exposure we reported. It is likely that over a course of a career, the average radiation exposure from BVNRFA will decrease for individual physicians. Though attendings who consistently teach new fellows each year and allow them to independently perform BVNRFA should particularly closely monitor their radiation exposure.

To the knowledge of the authors, this is the first study to publish reference ranges for radiation exposure for BVNRFA. The results of this study indicate that radiation exposure during BVNRFA is relatively high when compared to diagnostic imaging such as CTs but is comparable to orthopaedic surgeries. Given the relative novelty of BVNRFA, it would be beneficial for other institutions to report their average fluoroscopy exposure towards establishing reference doses for practitioner and trainees to strive towards and to aid the development of new techniques to optimize exposure.

5. Limitations

Our study has several limitations. The purpose of this study was to report the average fluoroscopic time and radiation dose. As such, this study did not report patient reported outcomes. Given that the purpose of our study was to report the average fluoroscopy time and radiation exposure during BVNRFA, we did not evaluate for any interventions used to decrease the exposure. Although this was a retrospective study, a prospective study would have been unlikely to have altered our results since we were not investigating specific variables. This study reported the fluoroscopic times of a single provider conducted within a single medical center. Our results may not be generalizable to other institutions that may use different procedure equipment and setting, physicians with variable years of experience, and patients with differing demographic makeup.

6. Conclusion

Our study reports the average fluoroscopic time for basivertebral nerve radio frequency ablations to be about two and a half minutes.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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