ORIGINAL ARTICLE

Examining the association of body mass index and the depth of epidural space, radiation dose exposure and fluoroscopic screening time during transforaminal nerve block injection: a retrospective cohort study

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Abstract

Objective The primary objective of this study was to examine the association between body mass index (BMI) and the depth of tissue overlying the epidural space. Secondary objectives examined the association between BMI and (1) radiation dose exposure and (2) fluoroscopic screening time during transforaminal nerve block (TFNB) injections.

Methodology This is a retrospective cohort study including patients aged ≥ 16 years who underwent unilateral single-level TFNB in a single centre over a 28-month period, by a single spinal orthopaedic surgeon. Demographic data, BMI (kg/m^2), fluoroscopic screening time (seconds) and radiation dose exposure (centi-gray per square centimetre squared ($cGy\text{-}cm^2$)) were recorded. *Exposure of interest*: BMI. *Primary outcome*: depth of epidural space. *Secondary outcomes*: (1) radiation dose exposure, (2) fluoroscopic screening time. Descriptive statistics for study participants' demographics are presented. Spearman's rank (r) coefficient and linear regression analysis was performed examining the association between BMI and the outcome measures.

Results A total of 362 patients met inclusion criteria; $n = 45$ patients were excluded due to incomplete data, final analysis included 317 patients. Mean age was 62.6 years (IQR 53–74). Male:female ratio was 37.9% ($n = 120$):62.1%($n = 197$). Mean BMI was 26.9 kg/m^2 (IQR 24.4–28.9 kg/m^2). Following adjustment for age, gender and spinal comorbidities there is a statistically significant association between BMI and the depth of tissue overlying the epidural space (adjusted coefficient 2.41, (95% CI (2.14, 2.68), $p < 0.001$)). We also found a significant association between BMI and both secondary outcomes, radiation dose exposure (adjusted coefficient 1.45, (95% CI (0.84, 2.06), $p < 0.001$)) and fluoroscopic screening time (adjusted coefficient 0.11, (95% CI (0.02, 0.20), $p = 0.02$)).

Conclusion This study has demonstrated a significant association between increasing BMI and increased depth of the epidural space. Furthermore, significant associations between increasing BMI, radiation dose exposure and fluoroscopy screening time have been identified. BMI may represent a modifiable risk factor with a view to decreasing patient exposure to medical ionised radiation.

Keywords Body mass index · Epidural space depth · Fluoroscopic screening time · Radiation dose exposure · Transforaminal nerve block

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Introduction

Transforaminal nerve block (TFNB) represents a widely accepted and effective treatment modality, utilised in the setting of lumbosacral radicular pain [1, 2]. Multiple factors are associated with optimal outcomes of this minimally invasive technique and rely upon accurate delivery of the injectate to the appropriate site [3–5]. Fluoroscopic imaging guidance aids the accurate placement of the injectate and is standard practice when performing such procedures, resulting in patient exposure to ionised radiation [6]. Exposure to ionised radiation has potential for the development of associated detrimental effects

such as dermal necrosis or tumour development [7–9]. Despite potential for development of these effects, there is an absence of consensus regarding the clinical significance of the adverse risk profile posed with this exposure [10].

Minimally invasive techniques have led to significant increases in the utilisation of radiological image guidance [2]. Obese patients (defined as body mass index (BMI) > 30 kg/m^2) are reportedly more likely to be exposed to larger doses of radiation [11–13]. This increased exposure is multifactorial and may be due to technical reasons including the depth of tissue (from skin to epidural space) that the needle must traverse to reach the desired location. As TFNBs represent a conservative therapeutic option for pain management, this patient cohort will often undergo repeat procedures, with each injection adding to their cumulative radiation profile and their potential for developing an adverse outcome [14].

Epidural spinal injections via transforaminal, caudal or interlaminar routes represent some of the most frequently utilised interventional procedures performed in North America [15]. A systematic review published in 2009 examined therapeutic lumbar transforaminal epidural steroid injections (TFESIs) demonstrating that TFESI's were effective for short-term relief of LBP [15]. DePalma et al. critically appraised the clinical evidence and outcomes pertaining to selective nerve root injection, concluding that there is currently limited level II and level III evidence supporting the case of minimally invasive transforaminal injections as effective procedures for the management of lumbosacral radicular pain [16]. The efficacy of this procedure remains undetermined as the current literature has failed to identify consistently reproducible beneficial outcomes from these injection procedures [15, 16]. Despite this definitive lack of clarity, demand for lumbosacral injections continues to increase.

Optimising clinical outcomes of this minimally invasive technique relies upon accurate delivery of the injectate to the appropriate anatomical site [17]. Without use of fluoroscopic guidance, the error rate in placing the injectate may be as high as 30%. Vad et al. demonstrated significantly improved clinical outcomes in patients receiving steroid injections under fluoroscopic guidance when compared to patients undergoing injections without guidance [3]. It is now common practice and essential to achieve accurate placement of the injectate with image guidance [4].

Currently, there remains much uncertainty when determining 'safe' levels of radiation exposure for patients. It is generally accepted that there is no amount of radiation that is completely without risk and the level of risk is proportional to the level of radiation exposure [18]. The Food and Drug Administration (FDA) states that, 'a CT examination with an effective dose of 10 millisieverts (abbreviated mSv; 1 mSv = 1 mGy in the case of x-rays.) may be associated with an increase in the possibility of fatal cancer of approximately 1 chance in 2000' [7]. This represents a

much smaller risk of an individual's lifetime natural risk of developing cancer [19]. However, it is not negligible and is additive to the lifetime natural risk for both patients and healthcare professionals.

The overall aim of this study is to examine the association between patient BMI and the depth of subcutaneous tissue overlying the epidural space. Secondary objectives include the following: (i). to determine the association between patient BMI and radiation dose exposure, and (ii) to determine the association between patient BMI and fluoroscopic screening time.

Methodology

This is a retrospective cohort study conducted in adherence with the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guidelines [20]. The study took place in a single institution. Ethical approval from the research ethics committee of the institution was obtained. All patients included within the study were ≥ 16 years of age. All patients who underwent single-level unilateral TFNB over a period of 28 months, from 1 January 2015 to 30 April 2017 were included. All procedures were performed by a single orthopaedic spinal surgeon, and multi-level or bilateral injections were excluded from the study.

Demographic data definitions and variables are presented in Table 1. Gender (male/female), date of birth, age (years and months), height (metres; m) and weight (kilogrammes; kg) were collected for each patient. BMI was calculated using the equation BMI (kg/m^2) = Weight (Kilogrammes, kg) / Height (metres^2, m^2). Using the Centre for Disease Control (CDC) and Prevention definitions, obesity was defined as (BMI ≥ 30 kg/m^2), overweight (25 kg/m^2 ≥ BMI < 30 kg/m^2), and normal BMI (BMI < 25 kg/m^2) [21]. Radiation exposure for each patient was collected; this takes the form of dose area product (centi-gray per centimetre squared; cGy/cm^2). The fluoroscopic screening time (seconds; s) per procedure was also recorded. The depth of tissue overlying epidural space (SE distance) was measured from T1-weighted sagittal images in the midline. This was recorded in millimetres (mm) from the ligamentum flavum at the level of the superior endplate of the fifth lumbar vertebrae (L5) to the overlying skin.

Potential confounding variables include the presence of underlying spinal disease, such as spinal stenosis, which may impede normal injection and increase difficulty of the procedure. Co-existing spinal pathology recorded in the database and accounted for in results analysis included spinal stenosis (SS), degenerative intervertebral disc disease (DDD), lumbar disc herniation (LDH), facet joint arthritis and foraminal stenosis.

Table 1 Definitions of variables of interest

Variable	Data	Units	Abbreviated units	Data source
BMI	Body mass index	Kilogrammes/(height in metres)^2	kg/m^2	Consultant Booking Form
Depth of tissue from skin to epidural space (SE distance)	Distance from skin to epidural space	Millimetres	mm	Impax
Radiation dose exposure	Dose area product	Centi-gray per centimetre squared	cGy/cm^2	Impax
Screening time	Fluoroscopic screening time	Seconds	s	Impax
Age	Date of birth	Years	Yr.	Impax
Gender	Male or female	Male/female	M/F	Impax

Statistical analysis

Bio-statistical analysis was undertaken using Stata/IC Windows (64bit) software (StataCorp, TX, USA). Descriptive statistics are presented for patient demographics (age, gender), BMI, presence of spinal comorbidity, side of procedure (left/right) and vertebral level of procedure. Spread of data was assessed for continuous variables using mean, standard deviation (SD) median and interquartile range (IQR). Number (n) and percentage (%) was performed for categorical variables. Spearman's rank (r) coefficient was utilised to determine correlations for this the nonparametric data set.

Linear regression analysis was undertaken using BMI ((kg/m^2): (continuous variable)) as the predictor of interest and epidural space depth (SE distance (mm)-continuous variable) as the outcome of interest controlling for confounding variables (i.e., age, gender, relevant spinal pathology). Unadjusted coefficients with 95% confidence intervals (CIs) and p values are presented in addition to adjusted coefficients (95% CIs, p value), following adjustment for relevant confounders. Furthermore, linear regression models were performed examining the association between BMI and secondary outcomes: (i) radiation dose exposure and (ii) fluoroscopic screening time, adjusting for relevant confounders.

Results

A total of 362 patients met the inclusion criteria, of which $n = 45$ (12.4%) had an incomplete dataset due to unavailability of externally performed MRI investigations. The final number of patients included in statistical analysis therefore was 317. The mean age of patients was 62 years, (S.D 15.31) with a median age of 64 years, interquartile range (IQR) 53–74 years. The mean participant BMI was 26.85 kg/m^2, (S.D 4.04) with a median BMI of 26.59 kg/m^2 (IQR 24.38–28.90 kg/m^2) and positively skewed indicating that the majority of patients within the study were either overweight (BMI ≥ 25, < 30, $n = 162$, 51.1%) or obese (BMI ≥ 30, $n = 58$, 18.3%). Approximately two-thirds of study participants were female, ($n = 197$, 62.1%) and $n = 120$ (37.9%) were male. There was no difference in the procedure side with an almost 50:50 division between left- ($n = 156$, 49.2%) and right-sided injections ($n = 161$, 50.8%). Of all TFNB injections performed, 93% ($n = 295$) were undertaken at the L4/5 ($n = 171$, 53.9%) or L5/S1 intervertebral levels ($n = 124$, 39.1%), respectively.

Mean SE depth for patients was 65.38 mm, ranging from 38 to 110 mm (SD 13.58, median 64.0 mm, IQR 55-74 mm). Mean radiation dose exposure was 28.86 cGy/cm^2, SD 13.58, median 23.38 cGy/cm^2 and IQR 16.04–36 cGy/cm^2. Mean screening time was 5.57 s, SD 3.14, median 5 s, IQR 4–7 s ranging from 1 to 28 s.

A summary of study participants' demographics is presented in Table 2.

The correlation between the predictor of interest (BMI) and outcomes of interest was assessed using the Spearman rank correlation coefficient. Statistically significant positive correlations were identified between BMI and the primary outcome of SE distance ($r = 0.72$, $p < 0.001$), and secondary outcomes of radiation dose exposure ($r = 0.34$, $p < 0.001$) and procedural fluoroscopic screening time ($r = 0.22$, $p < 0.001$). A summary of the results is presented in Table 3.

Linear regression analysis

Unadjusted and adjusted linear regression analysis was performed for primary and secondary outcome measures as previously outlined with BMI as the predictor of interest. For each outcome of interest, analysis was conducted controlling for confounding factors including age, sex and spinal comorbidities. Unadjusted and adjusted coefficients with 95% confidence intervals (CI's) and respective p values are presented. In the unadjusted model, increasing BMI was associated with an increased depth of tissue from skin to the epidural space (unadjusted coefficient 2.49, (95% CI (2.24, 2.74), $p < 0.001$). Following adjustment for age, gender and spinal

Table 2 Descriptive statistics for study participants (n = 317)

Variable	Mean	SD	Median	IQR	Range
Age (yr.)	62.58	15.31	64.0	53–74	16–92
BMI (kg/m^2)	26.85	4.04	26.59	24.38–28.90	18.45–49.35
SE depth (mm)	65.38	13.58	64.0	55–74	38–110
Radiation dose (cGy/cm^2)	28.86	21.47	23.38	16.04–36	2.21–209
Screening time (s)	5.57	3.14	5	4–7	1–28
Variable	BMI (kg/m^2)				Total (n, %)
	< 20	≥ 20, < 25	≥ 25, < 30	≥ 30	
Gender, n (%)					
Male	4 (50.0)	33 (37.08)	59 (36.42)	24 (41.38)	120 (37.85)
Female	4 (50.0)	56 (62.92)	103 (63.58)	34 (58.64)	197 (62.15)
Total (n)	8	89	162	58	317
Procedure side, n (%)					
Right	1 (12.5)	50 (56.18)	86 (53.09)	24 (41.38)	161 (50.79)
Left	7 (87.5)	39 (43.82)	76 (46.91)	34 (58.62)	156 (49.21)
Total (n)	8	89	162	58	317
Procedure level, n (%)					
L2/3	0	1 (1.12)	0	0	1 (0.32)
L3/4	0	8 (8.99)	12 (7.41)	1 (1.72)	21 (6.62)
L4/5	3 (37.50)	43 (48.31)	91 (56.17)	34 (58.62)	171 (53.94)
L5/S1	5 (62.50)	37 (41.57)	59 (36.42)	23 (39.66)	124 (39.12)
Total (n)	8	89	162	58	317
Spinal comorbidity					
Spinal stenosis, n (%)					
Yes	3 (37.50)	26 (29.21)	32 (19.75)	8 (13.79)	69 (21.77)
No	5 (62.50)	62 (69.66)	129 (79.63)	49 (84.48)	245 (77.29)
Degenerative disc disease, n (%)					
Yes	4 (50.0)	48 (53.93)	110 (67.90)	38 (65.52)	200 (63.09)
No	4 (50.0)	40 (44.94)	51 (31.48)	20 (34.48)	115 (36.28)
Lumbar disc herniation, n (%)					
Yes	6 (75.0)	76 (85.39)	129 (79.63)	42 (72.41)	253 (79.81)
No	2 (25.0)	12 (13.48)	32 (19.75)	16 (27.59)	
Facet joint arthritis, n (%)					
Yes	1 (12.50)	42 (47.19)	63 (38.89)	16 (27.59)	122 (38.49)
No	7 (87.5)	46 (51.69)	98 (60.49)	42 (72.41)	193 (60.88)
Foraminal stenosis, n (%)					
Yes	2 (25.00)	49 (55.06)	115 (70.99)	49 (84.48)	215 (67.82)
No	6 (75.00)	39 (43.82)	46 (28.40)	9 (15.52)	

IQR interquartile range, *SD* standard deviation, *BMI* body mass index

Table 3 Correlation between study participants' BMI (kg/m^2) and SE depth (mm), radiation dose exposure (cGy/cm^2) and screening time (seconds) (n = 317)

BMI (kg/m^2)	r	p value
SE depth	0.72	< 0.001
Radiation dose	0.34	< 0.001
Screening time	0.22	< 0.001
Radiation dose (cGy/cm^2)		
SE depth	0.29	< 0.001
Screening time	0.69	< 0.001

comorbidities, this association remained (adjusted coefficient 2.41, (95% CI (2.14, 2.68), $p < 0.001$) (Table 4).

In the unadjusted model, increasing BMI was associated with an increased radiation dose exposure (unadjusted coefficient 1.49, (95% CI (0.92, 2.05), $p < 0.001$). Following adjustment for relevant confounders, the association persisted (adjusted coefficient 1.45, (95% CI (0.84, 2.06), $p < 0.001$) (Table 5).

In the unadjusted model, increasing BMI was associated with an increase in fluoroscopic screening times (unadjusted coefficient 0.12, (95% CI (0.04, 0.21), $p < 0.001$). This

Table 4 Multivariable linear regression model of the unadjusted and adjusted coefficients (95% CIs, p value) for the primary outcome 'depth of tissue from skin to the epidural space (mm)' by exposure to BMI (kg/m^2) accounting for patient-level confounding variables (n = 317)

Variable	Unadjusted coefficient, (95% CI), p value	Adjusted coefficient, (95% CI) p value
BMI (kg/m^2)	2.49 (2.24, 2.74), $p < 0.001$	2.41 (2.14, 2.68), $p < 0.001$
Age	0.01 (− 0.09, 0.11), $p = 0.87$	− 0.34 (− 0.10, 0.03), $p = 0.33$
Sex	1.46 (− 1.62, 4.55), $p = 0.35$	2.56 (0.42, 4.71), $p = 0.02$
Spinal stenosis	− 3.34 (− 7.03, 0.16), $p = 0.06$	0.02 (− 2.54, 2.58), $p = 0.99$
Facet joint arthritis	− 0.74 (− 3.83, 2.35), $p = 0.64$	0.43 (− 1.87, 2.72), $p = 0.72$
Foraminal stenosis	7.40 (4.23, 10.52), $p < 0.001$	2.46 (0.17, 4.75), $p = 0.04$
Degenerative disc disease	3.06 (− 0.05, 6.17), $p = 0.05$	1.68 (− 0.52, 3.87), $p = 0.14$
Lumbar disc herniation	− 3.24 (− 7.02, 0.53), $p = 0.09$	− 1.04 (− 3.91, 1.82), $p = 0.24$

association persisted following adjustment for confounders (adjusted coefficient 0.11, (95% CI 0.02, 0.20), $p = 0.02$). Female gender was also associated with increased screening time (Table 6).

Discussion

Summary of findings

In this study, significant associations were identified between the predictor of interest, BMI and the outcome measures: (1) SE depth (adjusted coefficient 2.41, (95% CI (2.14, 2.68), $p < 0.001$), (2) radiation dose exposure (adjusted coefficient 1.45, (95% CI (0.84, 2.06), $p < 0.001$) and (3) fluoroscopic screening time (adjusted coefficient 0.11, (95% CI 0.02, 0.20), $p = 0.02$).

Comparison with existing literature

Low back pain (LBP) with radiculopathy is a common diagnosis and remains a difficult pathology to treat consistently and effectively [15, 22–25]. With the spread in use of radiologically assisted diagnostic and therapeutic techniques across medicine, patients are more likely to encounter ionised radiation. Subsequently, this has sparked an era of increased awareness of radiation safety and development of the concept of a

lifetime cumulative radiation exposure record [14]. Obesity has been identified as an independent risk factor for increased radiation exposure and the literature has shown that obese patients are more likely to sustain exposure to higher levels of ionised radiation during diagnostic and medical radiological procedures [11, 13]. As the incidence of obesity continues to rise, we cannot be sure of the potential long-term implications of ionised radiation exposure. TFNBs represent one of these radiologically assisted techniques which has grown in popularity for the management of radicular pain. Furthermore, this conservative treatment modality, as a temporary treatment measure, means patients often require repeat injections adding to their cumulative ionised radiation exposure.

This study has demonstrated a significant association between patient BMI and the depth of tissue overlying the epidural space (SE distance, mm) (adjusted coefficient 2.41). For every unit increase in BMI, the depth of the space increased by almost 2.5 mm. Ravi et al. conducted a prospective cohort study in patients undergoing epidural block prior to surgery or as a form of pain relief [26]. Measuring needle depth correlated with patient BMI, they reported that for all ages, the depth of epidural space from the skin was significantly greater in obese (BMI > 30 kg/m^2) than non-obese patients (BMI < 30 kg/m^2) ($p < 0.01$). Unlike much of the research pertaining to epidural space depth where depth is recorded subjectively from intra-procedural needle depth and liable to observer error, our study measured epidural space depth from

Table 5 Multivariable linear regression model of the unadjusted and adjusted coefficients (95% CI, p value) for the secondary outcome 'radiation dose exposure (cGy/cm^2)' by exposure to BMI (kg/m^2) and patient-level confounding variables (n = 317)

Variable	Unadjusted coefficient, (95% CI), p value	Adjusted coefficient, (95% CI) p value
BMI (kg/m^2)	1.49 (0.92, 2.05), $p < 0.001$	1.45 (0.84, 2.06), $p < 0.001$
Age	0.05 (− 0.11, 0.20), $p = 0.55$	0.03 (− 0.13, 0.18), $p = 0.74$
Sex	2.24 (− 2.63, 7.12), $p = 0.37$	2.89 (− 2.05, 7.82), $p = 0.25$
Spinal stenosis	− 4.74 (− 10.46, 0.99), $p = 0.11$	− 2.85 (− 8.72, 3.02), $p = 0.34$
Facet joint arthritis	2.22 (− 2.67, 7.10), $p = 0.37$	3.78 (− 1.50, 9.05), $p = 0.16$
Foraminal stenosis	4.58 (− 0.51, 9.67), $p = 0.08$	1.17 (− 4.09, 6.44), $p = 0.66$
Degenerative disc disease	− 0.33 (− 5.27, 4.62), $p = 0.90$	− 1.53 (− 6.58, 3.52), $p = 0.55$
Lumbar disc herniation	− 2.80 (− 8.78, 3.18), $p = 0.36$	0.29 (− 6.29, 6.86), $p = 0.93$

Table 6 Linear regression model with unadjusted and adjusted coefficients (95% CIs, p value) for the secondary outcome 'fluoroscopic screening time (seconds)' by exposure to BMI (kg/m^2) and adjustment for patient-level confounding variables $(n = 317)$

Variable	Unadjusted coefficient, (95% CI) p value	Adjusted coefficient, (95% CI), p value
BMI (kg/m^2)	0.12 (0.04, 0.21), $p < 0.001$	0.11 (0.02, 0.20), $p = 0.02$
Age	-0.01 $(-0.03, -0.01)$, $p = 0.49$	-0.02 $(-0.04, 0.00)$, $p = 0.11$
Sex	0.93 (0.23, 1.64), $p = 0.01$	1.18 (0.44, 1.91), $p < 0.001$
Spinal stenosis	-0.83 $(-1.66, 0.01)$, $p = 0.05$	-0.79 $(-1.65, 0.08)$, $p = 0.08$
Facet joint arthritis	-0.55 $(-1.26, 0.17)$, $p = 0.13$	-0.59 $(-1.37, 0.20)$, $p = 0.14$
Foraminal stenosis	0.36 $(-0.39, 1.11)$, $p = 0.34$	-0.06 $(-0.83, 0.72)$, $p = 0.88$
Degenerative disc disease	0.20 $(-0.53, 0.92)$, $p = 0.56$	0.36 $(-0.39, 1.10)$, $p = 0.35$
Lumbar disc herniation	-0.09 $(-1.26, 0.17)$, $p = 0.13$	-0.59 $(-1.56, 0.38)$, $p = 0.24$

corresponding MRI images improving the accuracy and consistency when recording SE distance [27–29].

Similarly, Brummet et al. in a small prospective observational study including 88 patients found a positive association ([RC] 1.13; $p < 0.001$) between the depth of epidural space and patient BMI [28]. Our research had the benefit of a considerably larger sample size $(n = 317)$. This confirmation of association between SE distance and BMI bears potentially significant patient impact. Previous research has shown that with increased depth of tissue, an increased intensity of ionised radiation is required to penetrate this tissue in order to reach the x-ray detector and create usable images [12, 13]. Subsequently, this results in patient exposure to a larger dose of ionised radiation and potential for development of adverse events [18, 30]. Identifying this association clarifies that BMI and SE depth may represent modifiable risk factors to reduce patient radiation exposure.

The results of this study have also demonstrated that for patients who are undergoing TFNB with fluoroscopic guidance, radiation dose exposure was positively correlated with increasing BMI, $r = 0.34$ and p value < 0.001. In a linear regression model with adjustment for relevant confounders, we found that increasing BMI was significantly associated with increased radiation dose exposure (adjusted coefficient = 1.45, (95% CI 0.84, 2.06), $p < 0.001$).

Fluoroscopic screening time indicates the time for which the x-ray tube is emitting ionised radiation. If multiple images are obtained during a procedure, the screening time represents a cumulative time measurement. Although BMI has been shown to have significant impact upon radiation dose exposure, the large series of images which are often generated in fluoroscopic procedures is likely to have a significant impact upon the fluoroscopic screening time; subsequently, fluoroscopic screening time is likely to be a determining factor in radiation dose exposure. We found a significant association between increasing BMI and longer fluoroscopic screening time (adjusted coefficient 0.11, (95% CI 0.02, 0.20), $p = 0.02$). Smuck et al. in a study of 202 patients undergoing zygapophyseal joint injection, medial branch nerve block and/or transforaminal epidural injection concluded that fluoroscopy time in patients with a BMI ≥ 25 kg/m^2 was increased by 30% and the procedure time was increased by 35% [31].

The mean screening time for TFNB injections in this study was 5.57 s (S.D 3.14). This is noticeably less than that which has been reported in previous studies. In a large retrospective review with 2443 TFNB injections, the mean fluoroscopy time was 30.5 s (SD 17.5); in contrast, the mean fluoroscopy time in a study conducted by Tiegs-Heiden et al. reported an appreciably longer fluoroscopic screening time of 138 s $(n = 1844$, SD 72) [32, 33]. The significant variation among these research groups is likely to be multifactorial in origin. Potential contributing factors include increased technical difficulty, difficulty in identifying anatomical surface landmarks, the need for adjustment of instrumentation, extended needle length and the necessity of repeat or 'check' imaging which are otherwise avoided in normal bodyweight individuals [32]. With spinal orthopaedic surgeons, anaesthetists, pain medicine specialists and radiologists all performing this type of procedure, the variation in their training background is likely to carrying significant impact. Furthermore, variable equipment between healthcare facilities and practice protocols would need to be taken into consideration.

Importantly, the results of this study indicate that both fluoroscopic screening time and radiation dose exposure are associated with BMI. However, other factors such as patient positioning, and technical issues such as departmental c-arm protocol settings and beam angulation may also have a role to play in screening time duration and could be examined in future research.

Strengths and limitations

The principle limitation of this study is its retrospective nature. As patients often undergo investigative imaging at tertiary radiology facilities, these images are often irretrievable on the inhouse radiology platform, resulting in

the generation of missing data. However, only $n = 45$ participants were excluded on this basis. The study design removed operator variability with all procedures having been performed by the same surgeon. However, this may reduce generalisability of the study findings as TFNB's are often performed by radiologists, anaesthetists and pain specialists alike.

This study included relevant confounders including age, gender and spinal comorbidities. There is scope for a prospective study which should aim to capture all potentially confounding factors influencing upon patient BMI such as thyroid disorders, Cushing's disease and steroid medication use. Other methods to determine level of obesity and fat distribution such as waist circumference or waist to hip ratio have not been considered in this study but could be considered in further research.

Conclusion

This study supports the hypothesis of the primary outcome that there is a significant association between increasing BMI and increased depth of tissue from the epidural space to the overlying skin. Furthermore, our study has indicated significant associations with respect to the secondary outcomes between increasing BMI, increased radiation dose exposure and fluoroscopy screening time during transforaminal nerve block injections.

Based on the European guidelines outlining safe thresholds for ionised radiation exposure, it is very unlikely the level of ionised radiation exposure solely from radiologically assisted spinal pain injections would pose risk to either patient or healthcare professional. However, the effects of an individual's cumulative exposure to ionised radiation remain somewhat unclear. In light of this, we recommend that the concept of "as low as reasonably achievable" should be implemented while performing radiologically assisted procedures with particular consideration given to overweight and obese patients. Ultimate care should be taken to maximise safety for patients and physicians alike.

Compliance with ethical standards

Conflict of interest The author declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Ethical approval was obtained from the healthcare institution prior to commencement of the study.

Informed consent For this type of study, formal consent is not required.

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