Effects of Preoperative Anxiety Status on Haemodynamic Changes during and after Tooth Extraction in Middle-aged and Elderly Patients with Hypertension: a Prospective Repeated-Measures Cohort Study

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Objective: *To investigate the effects of dental anxiety on fluctuations in blood pressure (BP) and heart rate (HR) during tooth extraction in hypertensive patients under local anaesthesia, and how they are influenced by various confounding variables.*

Methods: *This is a prospective repeated-measures cohort study involving 600 patients successively recruited from Peking University School and Hospital of Stomatology, Beijing, China. BP and HR were repeatedly measured at rest (T0), before anaesthesia (T1), during tooth extraction (T2) and after tooth extraction (T3). Anxiety status was measured prior to local anaesthesia using a modified dental anxiety scale (MDAS). Three groups were assigned: mild anxiety (Corah DAS score of 4 to 8), moderate anxiety (score of 9 to 12) and severe anxiety (score of 13 to 20). We used a generalised linear mixed model (GLMM) to analyse the effects of dental anxiety on fluctuations in BP and HR. Interaction analysis was used to further explore the correlationship between these interactive factors.*

Results: *The mean anxiety scale score was 9.63 ± 2.88. Severe preoperative anxiety (score of 14 to 20) was associated with significantly increased HR during administration of anaesthesia. Patients with severe anxiety also displayed a significantly greater increase in HR during anaesthetic administration ($P < 0.001$). When analysing the joint effects of different anxiety statuses over time, blood pressure was significantly elevated in all patients with moderate and severe anxiety during tooth extraction at T2 ($\beta = 1.25$, 95% CI 0.24 to 2.27). We also observed a significant decrease in HR in the moderate anxiety group at T3 ($\beta = -1.51$, 95% CI −2.38 to −0.63) and a significant increase in HR in the severe anxiety group at T1, T2 and T3 ($\beta = 2.52$, 95% CI 1.12 to 3.93; $\beta = 3.84$, 95% CI 2.30 to 5.38; $\beta = 4.57$, 95% CI 3.03 to 6.11, respectively).*

Conclusion: *This study indicates that the effects of dental anxiety on BP and HR in middle-aged and elderly patients with hypertension during local anaesthesia and tooth extraction were influenced by various confounding variables.*

Key words: *blood pressure, dental anxiety, extraction, heart rate, hypertension*
Chin J Dent Res 2021;24(4):267–274; doi: 10.3290/j.cjdr.b2440843

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Dental anxiety refers to patients' concerns and fears about the process of dental diagnosis and treatment. A survey found that 10.5% of patients among the general population undergoing dental extraction experienced dental anxiety[1]. The manifestation of sympathetic nerve hyperactivity[2], which is caused by dental anxiety during tooth extraction, is not conducive to safe clinical diagnosis and treatment of patients[3]. There is currently no unified risk assessment and management standard in the diagnosis and treatment manual of tooth extraction[4]. During tooth extraction operations, the patient's nervousness often induces a sudden increase in blood pressure (BP), which can exert stress on the heart of patients with cardiovascular diseases and potentially cause cerebrovascular accidents[5]. Previous studies have tracked changes in BP during tooth extraction[6,7]. When compared with non-hypertensive patients, changes in BP for hypertensive patients during tooth extraction are more significant[8].

Previous studies have shown that anxiety affects cardiovascular response indicators during tooth extraction, such as BP and heart rate (HR). A prospective cohort study of Indian patients showed that severe preoperative anxiety (dental anxiety scale [DAS] score > 12) was associated with a significant increase in HR and BP during anaesthesia[9]. Sharma et al[10] found that patients with severe anxiety also displayed a significantly greater increase in HR during anaesthetic administration. A recent study found a certain degree of correlation between BP and DAS score during tooth extraction in elderly patients with hypertension[11]. The more severe the dental anxiety, the higher the systolic and diastolic BP during tooth extraction, but the increase in HR was not significant[11]. Nevertheless, the results of these studies were not consistent. The HR of anxious patients did not increase significantly during dental extraction[12]; moreover, a study suggested that anxiety at baseline could not predict the increase in BP during tooth extraction[13]. It must be noted that dental anxiety is determined by many factors[1], such as sex, tooth extraction experience, type of tooth extraction (loose teeth, residual roots and crowns, impacted teeth), and psychological/mental state at the time of treatment. As such, these might be confounding factors in the association of dental anxiety with a cardiovascular response; however, previous studies did not adjust for such factors when exploring the influence of dental anxiety on cardiovascular response. Thus, no independent and accurate effect of anxiety on the outcome indicators has yet been discerned. We hypothesise that dental anxiety is modified by other factors, and that these in turn affect the correlation between anxiety and BP and HR during tooth extraction with local anaesthesia in hypertensive patients.

Therefore, the objective of this study is to further explore the impact of dental anxiety on changes in BP and HR in middle-aged and elderly hypertensive patients undergoing dental extraction with local anaesthesia while adjusting for potential confounding factors, so as to provide decision support for more precise treatment of dental extraction patients with hypertension.

Materials and methods

Study design and participants

This was a prospective repeated-measures cohort study. Patients were successively recruited from the Department of Geriatric Dentistry, Peking University School and Hospital of Stomatology, Beijing, China. The study population was specifically focused on dental patients with hypertension. According to the Chinese Guidelines for Prevention and Treatment of Hypertension (2018 Revised Edition)[14], patients were diagnosed with hypertension if, in the absence of anti-hypertensive medication, BP was measured in the office three times on different days and recorded as ≥ 140 mmHg (systolic) and/or ≥ 90 mmHg (diastolic). Considering that people with hypertension have a higher risk of BP fluctuation during tooth extraction surgery, which should be paid closer attention in clinical practice, and given the low prevalence of hypertension in young people, we took middle-aged and elderly patients with hypertension as the target group.

Inclusion and exclusion criteria

The inclusion criteria were as follows:
- patients diagnosed with hypertension;
- patients aged ≥ 45 years;
- patients willing to participate in the present study.

The exclusion criteria were as follows:
- patients with contraindications to tooth extraction;
- patients with a history of mental illness and unable to complete the questionnaire and anxiety scales;
- patients with anxiety disorders and those having taken anti-anxiety medication and sedatives within 3 days prior to tooth extraction;
- patients with poor blood pressure control and who had not taken anti-hypertensive drugs on the day of tooth extraction;
- patients allergic to local anaesthesia;
- patients with systemic disorders, such as cardiovascular disease and uncontrolled diabetes mellitus, or pregnancy.

Ethical approval was granted by the Peking University School and Hospital of Stomatology Research Ethics Committee. All participants provided written informed consent and were advised on the procedures and risks involved.

Procedures and measurement

The assessments of dental anxiety status are based on the modified Corah DAS (MDAS)[15]. The MDAS questionnaire was conducted by a trained researcher to assess patients' anxiety level while waiting for treatment. MDAS2 includes five questions that mention different, potentially frightening stimuli in response to which participants report the level of anxiety they experience using a 5-point scale with the following options: 'not anxious', 'slightly anxious', 'fairly anxious', 'very anxious' and 'extremely anxious'. The MDAS score ranges from 4 to 20, and on the basis of the scores, patients were divided into three groups: mild (4 to 8), moderate (9 to 12) and severe (> 12) dental anxiety.

After patients entered the consulting room, a senior oral surgeon performed anaesthesia and tooth extraction. During the entire process of tooth extraction, an electrocardiogram (ECG) monitored the patient's BP and HR at rest (T0), 3 minutes before anaesthesia (T1), during tooth extraction (T2) and 3 minutes after extraction (T3). Since a randomised clinical trial found that different anaesthetics have different effects on changes in blood pressure due to different proportions of adrenaline[11], only patients anaesthetised with articaine-adrenaline (1:100,000) were included in the present study.

Statistical analysis

Continuous variables were presented as mean ± SD, while categorical variables were presented as n (%). Variance analysis was used to analyse the means and proportions among the different anxiety groups. A Kruskal-Wallis test was used to compare continuous variables. To correlate the joint effect of anxiety with time, a generalised linear mixed model (GLMM) was used to analyse the significance of changes in BP and HR over time among the various groups. This model used a random intercept to account for repeated measurements on the same individual during tooth extraction. Time during extraction (T0, T1, T2 and T3) was treated as a categorical variable so that the relationship between strength and time was not skewed to be linear. The effect of other factors, including dental visits, extraction history, tooth loosening and tooth position, on the anxiety status was of interest; thus, the correlation between these factors and anxiety status was analysed. A two-tailed t test was carried out, with $P < 0.05$ considered to be statistically significant in all analyses. The data were analysed using R software (R Core Team, Vienna, Austria) and SPSS (IBM, Armonk, NY, USA).

Results

Initially, 610 patients were recruited into the study, before 10 were excluded because they did not meet the inclusion criteria. A total of 600 valid questionnaires were collected. The mean age of patients was 74.28 ± 9.90 years, and 285 were female (47.5%) and 315 were male (52.5%). The MDAS mean score was 9.63 ± 2.88. According to the MDAS, the participants were divided into three groups: mild (n = 219, 36.5%), moderate (n = 316, 52.7%) and severe anxiety (n = 65, 10.8%) (Fig 1).

The baseline characteristics of this cohort according to anxiety status (mild, moderate and severe) are presented in Table 1. The mean DAS score prior to administration of anaesthesia was 9.63 ± 2.88. Apart from age ($P > 0.05$), other variables including sex, educational level, types of medication, regularity of medication administration, extraction history, frequency of dental visits, tooth loosening and tooth position differed among the three groups ($P < 0.05$). Severe anxiety was more frequently observed in female patients and patients with a lower educational level, taking more than two types of medication, irregular medication administration, poor or no extraction history, low dental visit frequency and with those with loose teeth and an absence of posterior teeth.

The BP readings and HR in the different anxiety status groups at different time points during extraction are presented in Fig 2. Figs 2a and 2b illustrate changes in BP (systolic BP [SBP] and diastolic BP [DBP]) and HR in the three groups. SBP and DBP gradually increased, and the peak values were obtained at T2 during tooth extraction in the mild and moderate anxiety groups, and at T1 in the severe anxiety group. HR also gradually increased, and the peak values were obtained at T2 in all groups (Fig 2c).

Table 2 shows the estimates of the effects of anxiety status and time points alone and then together with the interaction of anxiety status and duration of extraction on SBP, DBP and HR. In the moderate and severe anxiety groups, SBP was significantly different to the mild anxiety group when adjusting for covariates including age, sex, educational level, types of medication, regularity of medication administration, frequency of dental

Table 1 Baseline characteristics of patients according to anxiety status prior to extraction.

Variable		Total	Mild anxiety	Moderate anxiety	Severe anxiety	*P* value
Age (y)		74.28 ± 9.90	75.05 ± 9.86	73.66 ± 10.50	74.68 ± 6.34	0.259
Sex	Male	285 (47.50%)	133 (60.73%)	131 (41.46%)	21 (32.31%)	< 0.001*
	Female	315 (52.50%)	86 (39.27%)	185 (58.54%)	44 (67.69%)	
Education level	Lower	354 (59.00%)	100 (45.66%)	208 (65.82%)	46 (70.77%)	< 0.001
	Higher	246 (41.00%)	119 (54.34%)	108 (34.18%)	19 (29.23%)	
Types of medication	≥ Two types	237 (39.50%)	74 (33.79%)	130 (41.14%)	33 (50.77%)	0.033*
	One type	363 (60.50%)	145 (66.21%)	186 (58.86%)	32 (49.23%)	
Medication taken as prescribed	Yes	185 (30.83%)	35 (15.98%)	125 (39.56%)	25 (38.46%)	< 0.001*
	No	415 (69.17%)	184 (84.02%)	191 (60.44%)	40 (61.54%)	
Extraction history	Good	315 (52.50%)	167 (76.26%)	131 (41.46%)	17 (26.15%)	< 0.001*
	Regular	200 (33.33%)	44 (20.09%)	142 (44.94%)	14 (21.54%)	
	Pain	47 (7.83%)	8 (3.65%)	28 (8.86%)	11 (16.92%)	
	No history	38 (6.33%)	0 (0.00%)	15 (4.75%)	23 (35.38%)	
Time since last dental visit	< 1 y	311 (51.83%)	127 (57.99%)	164 (51.90%)	20 (30.77%)	< 0.001*
	1–5 y	140 (23.33%)	55 (25.11%)	62 (19.62%)	23 (35.38%)	
	> 5 y	149 (24.83%)	37 (16.89%)	90 (28.48%)	22 (33.85%)	
Tooth loosening	Yes	264 (44.00%)	83 (37.90%)	137 (43.35%)	44 (67.69%)	< 0.001*
	No	336 (56.00%)	136 (62.10%)	179 (56.65%)	21 (32.31%)	
Tooth position	Anterior	144 (24.00%)	95 (43.38%)	34 (10.76%)	15 (23.08%)	< 0.001*
	Posterior	456 (76.00%)	124 (56.62%)	282 (89.24%)	50 (76.92%)	
MDAS score		9.63 ± 2.88	6.59 ± 1.65	10.76 ± 1.17	14.40 ± 0.61	< 0.001*

*$P < 0.05$.

visits, extraction history, tooth loosening and tooth position (β = 5.8, 95% CI 2.76 to 8.85 and β = 15.40, 95% CI 10.51 to 20.29, respectively). When only considering the effects of time, SBP was significantly higher at T1 and T2 than at T0 (β = 6.30, 95% CI 4.98 to 7.61 and β = 9.24, 95% CI 7.92 to 10.55, respectively), but no significant differences were recorded at T3 when compared to T0 ($P = 0.135$). However, when considering the joint effects of different anxiety status with time, a significant difference was only found with the moderate anxiety group at T2 (β = 3.48, 95% CI 1.77 to 5.20) and the severe anxiety group at T2 (β = −11.27, 95% CI −14.02 to −8.52) and T3 (β = −8.94, 95% CI 11.70 to −6.19). SBP was significantly lower in the severe anxiety group at T2. Thus, with regard to the SBP index, more attention needs to be paid at T2 for all three groups. With regard to DBP, the moderate anxiety group recorded higher levels than the mild anxiety group after adjusting for covariates (β = 2.71, 95% CI 0.75 to 4.66), but no significant differences were found in the severe anxiety group ($P = 0.114$). When only considering the effects of time, DBP was significantly higher at T1 and T2 than at T0 (β = 2.42, 95% CI 1.64 to 3.20 and β = 3.00, 95% CI 2.22 to 3.78, respectively), but significantly lower at T3 when compared to T0 (β = −1.02, 95% CI −1.80 to −0.24). However, when considering the joint effects of different anxiety status with time, significant differences were only found with the moderate anxiety group at T2 (β = 1.25, 95% CI 0.24 to 2.27). DBP was significantly lower in the severe anxiety group at T2. Thus, for the DBP index, more attention needs to be paid at T2 for the moderate anxiety group.

HR was also significantly higher in the moderate anxiety group than the mild anxiety group after adjusting for covariates (β = 2.44, 95% CI 0.48 to 4.40), but no significant differences were found in the severe anxiety group ($P = 0.761$). When only considering the effects of time, HR was significantly higher at T1, T2 and T3 than at T0 (β = 3.66, 95% CI 2.99 to 4.34; β = 6.20, 95% CI 5.52 to 6.87; and β = 0.90, 95% CI 0.23 to 1.58, respectively). When considering the joint effects of different anxiety status with time, HR was found to be significantly lower in the moderate anxiety group at T3 (β = −1.51, 95% CI −2.38 to −0.63), and significantly higher in the severe anxiety group at T1, T2 and T3 (β = 2.52, 95% CI 1.12 to 3.93; β = 3.84, 95% CI 2.30 to 5.38; and β = 4.57, 95% CI 3.03 to 6.11, respectively). Thus, for the HR index, more attention needs to be paid at T2 for the moderate anxiety group and at T1, T2 and T3 for the severe anxiety group.

To further explore the impact of dental anxiety on hypertensive patients undergoing tooth extraction,

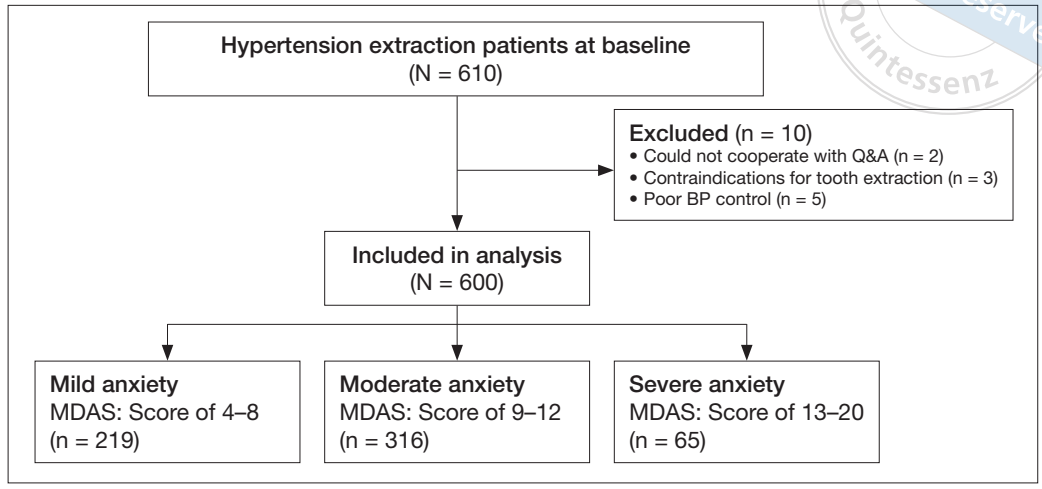

Fig 1 Flowchart of outcomes according to dental anxiety status (MDAS).

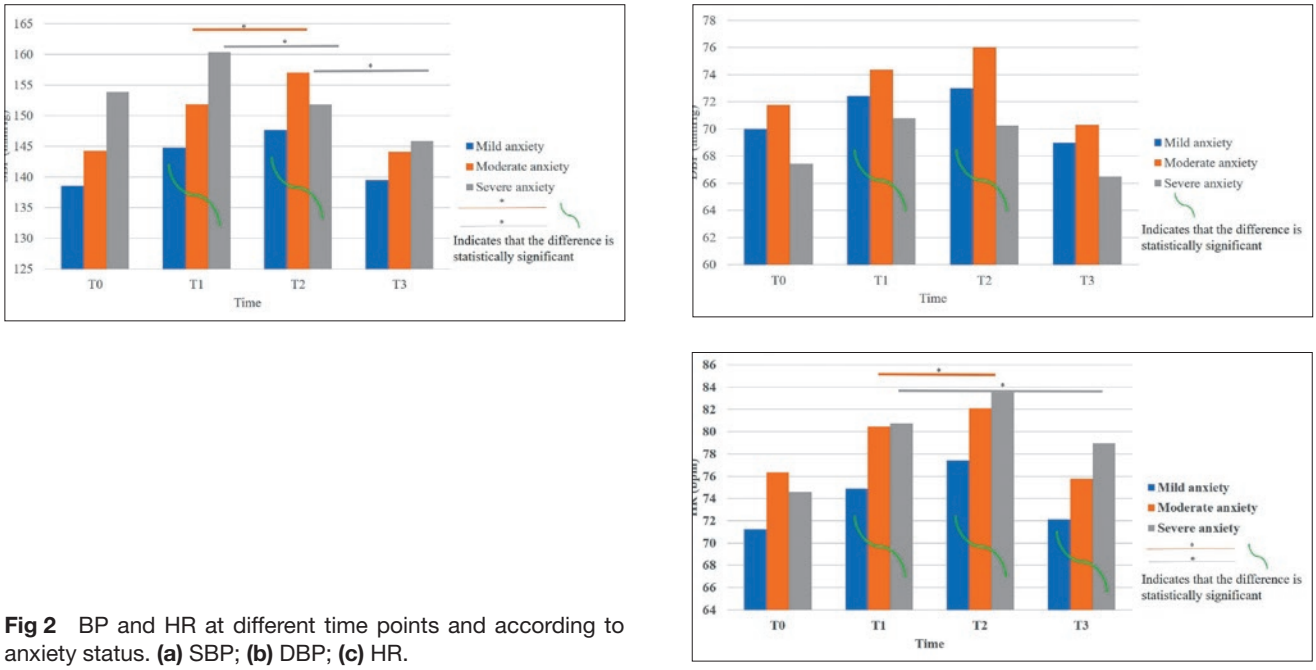

Fig 2 BP and HR at different time points and according to anxiety status. **(a)** SBP; **(b)** DBP; **(c)** HR.

we conducted an interaction analysis. The results of this analysis with a GLMM on SBP, DBP and HR are shown in Table 3. We found that there were interactions between dental anxiety and six variables: types of medication, regularity of medication administration, extraction history, dental visit interval, extraction type and tooth position. Further subgroup analysis results are not shown (provided on request).

Discussion

In this prospective repeated-measures study, we explored the effects of dental anxiety on the BP and HR of patients with hypertension during dental extraction under local anaesthesia. First, we found that dental anxiety exerts a certain independent effect on BP and HR during tooth extraction in patients with hypertension. After adjusting for potential confounding factors and considering joint fixed effects (dental anxiety) and random effects (time), we observed that the moderate anxiety group had the highest fluctuations in SBP and DBP at T2, whereas the severe anxiety group did not seem to show much correlation between increased BP and various time points. On the contrary, SBP in the severe anxiety group at T2 and T3 decreased significantly. This indicates that the impact of anxiety on SBP and DBP may be affected by confounding factors such as medication and the condition of the teeth being extracted. The HR of patients with moderate anxiety at T3 and of those with severe anxiety at T1, T2 and T3 was significantly higher ($P < 0.001$).

Table 2 Estimates of the effects of anxiety status and time points alone, and interaction of anxiety status and duration of extraction with SBP, DBP and HR.

Variable		Crude model (β [95% CI])	*P* value	Adjust model (β [95% CI])	*P* value
SBP	MDAS:Moderate anxiety	5.81 (2.76, 8.85)	< 0.001#	6.02 (2.71, 9.32)	< 0.001#
	MDAS:Severe anxiety	15.40 (10.51, 20.29)	< 0.001#	13.85 (8.83, 18.87)	< 0.001#
	Time:T1	6.30 (4.98, 7.61)	< 0.001#	6.30 (4.98, 7.61)	< 0.001#
	Time:T2	9.24 (7.92, 10.55)	< 0.001#	9.24 (7.92, 10.55)	< 0.001#
	Time:T3	1.00 (–0.31, 2.32)	0.134	1.00 (–0.31, 2.32)	0.135
	MDAS:Moderate anxiety * Time:T1	1.31 (–0.40, 3.02)	0.132	1.31 (–0.40, 3.03)	0.133
	MDAS:Moderate anxiety * Time:T2	3.48 (1.77, 5.19)	< 0.001#	3.48 (1.77, 5.20)	< 0.001#
	MDAS:Moderate anxiety * Time:T3	–1.17 (–2.88, 0.54)	0.179	–1.17 (–2.89, 0.54)	0.180
	MDAS:Severe anxiety * Time:T1	0.24 (–2.51, 2.99)	0.863	0.24 (–2.51, 2.99)	0.863
	MDAS:Severe anxiety * Time:T2	–11.27 (–14.02, –8.52)	< 0.001#	–11.27 (–14.02, –8.52)	< 0.001#
	MDAS:Severe anxiety * Time:T3	–8.94 (–11.69, –6.20)	< 0.001#	–8.94 (–11.70, –6.19)	< 0.001#
DBP	MDAS:Moderate anxiety	1.75 (–0.08, 3.58)	0.061	2.71 (0.75, 4.66)	0.007#
	MDAS:Severe anxiety	–2.56 (–5.50, 0.38)	0.088	–2.40 (–5.37, 0.57)	0.114
	Time:T1	2.42 (1.64, 3.19)	< 0.001#	2.42 (1.64, 3.20)	< 0.001#
	Time:T2	3.00 (2.22, 3.77)	< 0.001#	3.00 (2.22, 3.78)	< 0.001#
	Time:T3	–1.02 (–1.80, –0.24)	0.010#	–1.02 (–1.80, –0.24)	0.010#
	MDAS:Moderate anxiety * Time:T1	0.20 (–0.81, 1.21)	0.701	0.20 (–0.82, 1.21)	0.702
	MDAS:Moderate anxiety * Time:T2	1.25 (0.24, 2.27)	0.015#	1.25 (0.24, 2.27)	0.016#
	MDAS:Moderate anxiety * Time:T3	–0.44 (–1.46, 0.57)	0.392	–0.44 (–1.46, 0.57)	0.393
	MDAS:Severe anxiety * Time:T1	0.94 (–0.69, 2.57)	0.259	0.94 (–0.69, 2.57)	0.260
	MDAS:Severe anxiety * Time:T2	–0.18 (–1.81, 1.45)	0.828	–0.18 (–1.81, 1.45)	0.829
	MDAS:Severe anxiety * Time:T3	0.07 (–1.56, 1.70)	0.934	0.07 (–1.56, 1.70)	0.934
HR	MDAS:Moderate anxiety	5.15 (3.26, 7.04)	< 0.001#	2.44 (0.48, 4.40)	0.015
	MDAS:Severe anxiety	3.35 (0.32, 6.39)	0.031	0.46 (–2.52, 3.44)	0.761
	Time:T1	3.66 (2.99, 4.33)	< 0.001#	3.66 (2.99, 4.34)	< 0.001#
	Time:T2	6.20 (5.52, 6.87)	< 0.001#	6.20 (5.52, 6.87)	< 0.001#
	Time:T3	0.90 (0.23, 1.58)	0.008	0.90 (0.23, 1.58)	0.009#
	MDAS:Moderate anxiety * Time:T1	0.44 (–0.43, 1.32)	0.322	0.44 (–0.43, 1.32)	0.322
	MDAS:Moderate anxiety * Time:T2	–0.47 (–1.34, 0.41)	0.297	–0.47 (–1.34, 0.41)	0.298
	MDAS:Moderate anxiety * Time:T3	–1.51 (–2.38, –0.63)	< 0.001#	–1.51 (–2.38, –0.63)	< 0.001#
	MDAS:Severe anxiety * Time:T1	2.52 (1.12, 3.93)	< 0.001#	2.52 (1.12, 3.93)	< 0.001#
	MDAS:Severe anxiety * Time:T2	3.81 (2.27, 5.35)	< 0.001#	3.84 (2.30, 5.38)	< 0.001#
	MDAS:Severe anxiety * Time:T3	4.54 (3.00, 6.08)	< 0.001#	4.57 (3.03, 6.11)	< 0.001#

#*P* < 0.05. Statistical analysis method: GLMM. Crude model adjusted no variables; adjusted model adjusted age, sex, education level, kinds of medication, regularity of medication administration, time since last dental visit, extraction history, tooth loosening and tooth position. MDAS:Moderate anxiety, take the mild anxiety group as reference, the effect of moderate anxiety on outcomes; Time:T1, take T0 as reference, the effect of T1 on outcomes; MDAS:Moderate anxiety * Time:T1, how much more BP changed at T1 than at T0 in the other groups compared to moderate anxiety.

A previous study found that dental anxiety impacted the effects of delivery of local anaesthesia on BP and is significantly associated with increased HR[16]. SBP and DBP showed significant changes; the highest value was recorded at the time of ostectomy/tooth sectioning, which was similar to our findings in patients with mild and moderate anxiety (the highest value for BP was at tooth extraction; however, BP peaked at T1 (before anaesthesia) in patients with severe anxiety. This study found that maximum HR was observed 4 minutes after local anaesthetic injection and the lowest HR was recorded after completion of tooth extraction, i.e., during suturing, which was consistent with previous findings[16]. Another study suggested that dental anxiety was related to preoperative DBP (pre-DBP) ($P = 0.001$) and postoperative DBP (post-DBP), as well as preoperative HR (pre-HR) ($P = 0.027$) and postoperative HR (post-HR) ($P = 0.013$)[17]. These findings are also consistent with the results of this study.

In a previous prospective repeated-measures study, Silvestre et al[12] showed that the more severe the dental anxiety, the higher the SBP and DBP during tooth extraction, but the increase in HR was not significant; however, these results are not consistent with the find-

Table 3 Results of the interaction analysis in a GLMM for SBP, DBP and HR.

Interaction factors	SBP		DBP		HR	
	F value	*P* value	F value	*P* value	F value	*P* value
Time*Kinds of medication*Anxiety status	10.52	< 0.001#	3.168	< 0.001#	5.685	< 0.001#
Time*Regularity of medication administration*Anxiety status	13.26	< 0.001#	10.757	< 0.001#	11.91	< 0.001#
Time*Extraction history*Anxiety status	14.371	< 0.001#	11.047	< 0.001#	8.568	< 0.001#
Time*Dental visit interval*Anxiety status	7.477	< 0.001#	24.586	< 0.001#	9.234	< 0.001#
Time*Extraction type*Anxiety status	5.572	< 0.001#	37.008	< 0.001#	5.860	< 0.001#
Time*Tooth position*Anxiety status	6.125	< 0.001#	9.454	< 0.001#	7.440	< 0.001#

#*P* < 0.05, significant interaction.

ings of the present study. Most of the variables, such as medication type, regularity of medication administration and frequency of dental visits, were significantly different between the three groups, indicating that confounding factors influenced the association of dental anxiety with BP and HR. In addition, further interactive analysis found that the medication status, frequency of dental visits, type of tooth extraction, tooth mobility and teeth of patients with dental anxiety and hypertension are key confounding variables in the correlation between dental anxiety and BP and HR, thus providing decision support for more precise clinical dentistry.

It is worth noting that the present study found that patients with moderate anxiety presented higher SBP and DBP than those with severe anxiety, which seems to differ from the results of previous studies[9,10,12]; however, this result may be due to the interaction between anxiety status and other modified factors. When examining variables related to BP medication, we found that a significantly higher proportion of patients suffer from severe anxiety towards tooth extraction when using two or more kinds of medication than moderate anxiety. In addition, a significantly higher number of patients undergoing extraction of loose teeth experienced severe anxiety than moderate anxiety. Moreover, patients with severe anxiety during anterior tooth extraction were less likely to suffer from severe anxiety than patients with the same degree of anxiety. These factors were associated with increased BP. Therefore, in our clinical practice, higher anxiety levels do not necessarily lead to a greater fluctuation in BP; it is also necessary to consider the medication taken by patients with hypertension and who require tooth extraction, regardless of whether the teeth to be extracted are loose or not, and whether they are anterior or posterior teeth. The results of interaction in this study could further promote personalised diagnosis and treatment in tooth extraction for patients with hypertension.

The increase in HR and change in BP during injection may be due to the release of endogenous adrenaline caused by emotional stress. Therefore, based on the results of this study, we believe that it is important to offer patients preoperative psychological counselling, particularly those with severe anxiety, to minimise the risk of cardiovascular accidents in patients with hypertension during dental extraction under local anaesthesia. There are two major sources of anxiety during the tooth extraction procedure: anxiety caused by anaesthesia, and anxiety caused by tooth extraction. For anxiety caused by anaesthesia, the dental practitioner can apply topical anaesthetics and oral anaesthetic gel prior to anaesthesia to reduce the pain during injection[18]. During tooth extraction, it is suggested that some measures can be taken to reduce patients' anxiety, such as psychological nursing intervention based on relaxation training[7] and listening to music[19], or even taking tranquilisers[20], which would be beneficial to the process of surgery and help to reduce cardiovascular accidents during surgical procedures.

In the present study, the use of GLLM took into full consideration both random and fixed effects in the same patient. We also identified the confounding variables that influence how anxiety affects BP and HR, which provides strong evidence for which particular patient population should be given more attention in the clinic. Nevertheless, there are also some limitations to this study. Multiple time points during the tooth extraction process, many confounding factors such as pain, and the influence of confounding factors, as well as other indicators, including ECG and ambient oxygen saturation, were not taken into account. Such observation indicators should therefore also be included in future studies.

Conclusion

The present study thus suggests that dental anxiety independently affects BP and HR during tooth extraction in middle-aged and elderly patients with hypertension. The effect of anxiety on cardiovascular response was modified by various interactive factors such as drug admin-

istration, extraction history, frequency of dental visits, extraction type and tooth position.

Conflicts of interest

The authors declare no conflicts of interest related to this study.

Author contribution

Dr Jing Ying HU designed and supervised all the procedures and critically revised the manuscript; Dr Qian Mei ZHOU conceived of the presented idea, collected and analysed the data and revised the manuscript; Dr Wen Jing LI drafted the manuscript, analysed the data and revised the manuscript; Dr Xu Liang DENG designed the study; Drs Wen Ying WANG and Jin Wei HUANG took part in the discussion and provided valuable suggestions; Dr Ran Li HUANG collected the data. All authors discussed the results and contributed to the final manuscript.

(Received Jul 19, 2021; accepted Sep 09, 2021)

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