Fractional spinal anesthesia and systemic hemodynamics in frail elderly hip fracture patients

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Research Article

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Posted Date: November 11th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-1053831/v1

RESEARCH

Fractional spinal anesthesia and systemic hemodynamics in frail elderly hip fracture patients.

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Abstract

Background: Aging and frailty make the elderly patients susceptible to hypotension following spinal anesthesia. The systemic hemodynamic effects of spinal anesthesia are not well known. In this study, we examine the systemic hemodynamic effects of fractional spinal anesthesia following intermittent microdosing of a local anesthetic and an opioid.

Methods: We included 15 patients aged over 65 with considerable comorbidities, planned for emergency hip fracture repair. Patients received a spinal catheter and cardiac output monitoring using the LiDCOplus system. Invasive mean arterial pressure (MAP), cardiac index, systemic vascular resistance index, heart rate and stroke volume index were registered. Two doses of bupivacaine 2.25 mg and fentanyl 15µg were administered with 25 minutes in between. Hypotension was defined as a fall in MAP by >30% or a MAP <65 mmHg

Results: The incidence of hypotension was 30%. Hypotensive patients (n=5) were treated with low doses of norepinephrine (0.003-0.12 µg/kg/min). MAP showed a maximum reduction of 17% at 10 minutes after the first dose. Cardiac index, systemic vascular resistance index and stroke volume index decreased by 10%, 6%, and 7%, respectively, while heart rate was unchanged over time. After the first dose, none of the systemic haemodynamic variables were affected.

Conclusion: Fractional spinal anesthesia causes a low incidence of hypotension, induced mainly by a systemic venodilation, causing a decrease in venous return and fall in cardiac output. Our results show that fractional spinal anesthesia is a safe technique from a hemodynamic point of view and is probably underutilized in high-risk, elderly hip fracture patients

Keywords: Spinal anaesthesia; fractional; hip fracture surgery; cardiac output; hypotension

Background

A hip fracture in the elderly frail patient poses a major anesthesiologic challenge as these patients are mostly presented off-hours and many have comorbidities. The 30-day mortality among acute hip fracture (AHF) patients is as high as 6-10 % [1]. Many factors affect the mortality, some of those are time to start-of-surgery[2], cementation of hemi- or total arthroplasty[3], and preoperative morbidity assessed by American Society of Anaesthesiologist (ASA) risk score and Nottingham Hip Fracture Score (NHFS)[4, 5]. Preoperative cardiology consulting, however, rarely affects surgical management, but could alter anesthesiologic management[6].

The peri-operative anaesthesia strategy of the frail AHF patient differs worldwide, where many centers give general anaesthesia, while particularly in norther Europe, neuraxial anaesthesia is the preferred technique[7]. However, both techniques frequently induce hypotension treated by fluid resuscitation and/or vasopressors. Perioperative hypotension is a problem disposing patients to organ hypoperfusion with consequences as; myocardial injury, delirium and renal failure[8]. The physiological origin of the hypotension is unclear, but many anesthesiologists believe that the decrease of systemic vascular resistance is the main cause of hypotension[9], while others believe that hypotension is caused by a fall in cardiac output[10]. In our hospital, we routinely administer neuraxial anesthesia when operating the hip fracture patient. We have achieved a great experience with this technique and in the present study, we hypothesize that the induction of fractional spinal anesthesia by an indwelling intrathecal catheter[11] would reduce the incidence and degree of hypotension.

The aim of the present study was two-fold: firstly we aimed to evaluate the incidence of hypotension by using this technique to administer low concentrations and volumes of mixtures of a local anesthetic[12]. Secondly we wanted to study, in more detail, the systemic hemodynamic response to fractional spinal anesthesia in this group of elderly frail patients with an AHF. We utilized the LiDCOplus system to monitor pre-surgical hemodynamic changes over time. LiDCOplus is a validated system where lithium dilution technique is used to calibrate the arterial pulse contour analysis[13]. The LiDCO system has previously been used in these patients in the perioperative setting[14, 15, 16]. The advantage of LiDCO compared to other hemodynamic devices is that lithium can be injected in a peripheral venous cannula and then lithium concentration is captured through a standard 20G arterial cannula. Thus, we could avoid more invasive monitoring using central venous catheters, femoral arterial cannula or the Swan-Ganz catheter.

Methods

Ethical approval was granted by the Ethics Committee (Dnr 2020-05684). We daily screened patients planned for hip fracture surgery and these were identified through the theater planning software (Orbit, TietoEVRY, Espoo, Finland). Inclusion criteria were: 1) patient with hip fracture, 2) >65 years of age, 3) ASA $\leq$2, 4) scheduled for neuraxial anesthesia and 5) mentally intact to give informed consent. This could also be given by next-of-kin, if the patient was cognitively impaired. Exclusion criteria were: a) lithium or anticoagulation medication, b) planned for general anesthesia, c) ongoing atrial fibrillation, d) if surgery was delayed >72 hours, e) lack of informed consent and f) patient agitation requiring intermittent sedation. Finally, inclusion rate was dependent and affected by the primary investigator's availability and the operative capacity. Nottingham Hip Fracture Score was calculated. This scoring system includes objective factors like age, sex, dementia, previous cancer, living facility and comorbidity. NHFS varies from 1-10 with higher numbers correlated to higher 30-day mortality[5, 17]. ASA grade was also recorded after study inclusion.

After arriving to the preoperative area, patients were given 5 liters of oxygen on a face mask and ECG and pulse-oximetry monitoring were started. Oral premedication with standardized doses of paracetamol and oxycodone was given orally,

followed by the placement of a venous 18G cannula in an antecubital vein and a radial arterial catheter (20G). The patient was also given a fascia iliaca compartment (FIC) block, or an ultrasound guided femoral nerve block with ropivacaine 3.5mg/ml 20-40ml, to decrease discomfort when given the neuraxial block. In addition, the LiDCOplus (LiDCO Group Plc, London, England) system was set up according to manufacturer's instructions. The system was calibrated with 0.3-0.45 mmol lithium chloride depending on body weight. After calibration and baseline parameter registration, the LiDCOplus system provided cardiac output variables and based on these and the invasive blood pressure, hemodynamic variables could be derived, see table 2.

Following aseptic skin preparation of the lumbar area, a subarachnoid puncture by a 18G Tuohy needle was performed either between the L2 - L3 or the L3 - L4 interspaces, preferably using a mid-line approach. An intrathecal catheter 20G was then inserted 4-5 cm into the intrathecal space. This technique of a continues spinal anesthesia (CSA) was performed on all patients by one physician (FO). A solution (10 ml) containing 1.5 mg/ml bupivacaine and 10 µg/ml fentanyl was prepared. Intrathecal anesthesia was induced by giving 1,5 ml (2.25 mg of bupivacaine and 15 µg of fentanyl) of the solution, followed by a second 1.5 ml injection after 25 min (i.e., a total intrathecal dos of 4.5 mg of bupivacaine and 30 µg of fentanyl). Sensory level was monitored by "cold spray". Hemodynamic recordings were performed every 5 minutes up until 45 minutes after initial intrathecal dose when research monitoring was terminated. The patient was then operated in the pre-planned time slot and was further managed at the discretion of the attending anesthetist. Mean arterial blood pressure (MAP) was maintained, when needed, with a nor-epinephrine infusion to target a MAP >65mmHg or to avoid a $>$ 30% decline in MAP from the baseline level. The invasive hemodynamic parameters were recorded every 5 min for 45 min after initial intrathecal dose was given. In addition to SaO2 and ECG, the following parameters were recorded; cardiac index (CI), stroke volume index (SVI), systemic vascular resistance index (SVRI), systolic arterial pressure, (SAP), diastolic arterial pressure (DAP), MAP and norepinephrine doses over time. Finally, effective arterial elastance (EA) was calculated by the formula; 0,9*SAP/SV[18]. For indexing parameters, the du Bois and du Bois formula for Body Surface Area (BSA) was used[19].

Statistics

Statistical analysis was performed with RStudio for Mac (version 1.2.5033) and GPower version 3.1.9.6 (Franz Faul, Universität Kiel, Germany) to determine sample size. Normality was assessed with Shapiro-Wilks test prior to deciding appropriate variation testing, one-way repeated measures ANOVA for normally distributed and Friedmann test for non-normal distributions. For repeated measures, ANOVA was utilized to study changes in hemodynamic variables over time. A $p < 0.05$ was considered statistically significant. A sample size of n=13 patients for the repeated measured ANOVA was needed to have an 80% power (β= 0.20) for detection the effect size F=0.25 (α= 0.05).

Results

The clinical trial profile is shown in Fig 1. Twenty-four patients were eligible for the study, 15 of those were finally included. Two patients withdrew previous informed consent, 2 patients were excluded as of logistical problems, 2 patients were excluded as of agitated dementia and finally, 3 patients were excluded as of having new neurological symptoms. Hypertension was the dominant comorbidity present in 73% of patients, dementia was also prevalent with 47%. Prior or present malignancy was found in 33% of patients. Further demographic data of the studied patients are summarized in Table 1.

The study population had a median age of 89 years and consisted primarily of women (12/15). The median ASA grade was 3 (range 2- 4) and the median NHFS score was 5 (range 4-7). Furthermore, no patients had significant arrythmias during the experimental procedure and none required vasopressor support prior to the first intrathecal dose of the bupivacaine/fentanyl solution was given. Sensory and motor function were assessed, revealing that all patients had satisfactory level of sensory block at minimum Th 12 documented with sensation to cold or painful reaction to flexion of the hip. In mentally intact patients, all had a temperature discrimination demonstrated by a sensory block $<$ Th 8 level. Further, we noticed a high incidence of retained motor function after the initial neuraxial 1.5 ml dose (2.25 mg bupivacaine and 15 µg fentanyl), possibly due to a less dense blockade.

Data on systemic hemodynamics are shown in Fig. 2-7. MAP, CI, SVRI, SVI and arterial elastance were all found to have normal distribution at each point of measurement according to Shapiro-Wilks's test. After applying the one-way repeated measures ANOVA test, MAP, SVRI, SVI and CI all showed significant variance over time. Thus, MAP decreased by 17% from baseline with the lowest mean noted at 10 min after the first intrathecal dose was given. CI was reduced by 10% also after 10 minutes. SVRI showed a 6% reduction from baseline found directly after the intrathecal dose was given. SVI dropped by 7% with a lowest mean value at 10 minutes after anesthesia induction and, finally, heart rate decreased non-significantly by 3% from baseline. Elastance showed no significant variation over time as measured by ANOVA. The largest reduction from the baseline value was -10% at 5 min after the initial spinal dose. One third (5/15) of patients required norepinephrine infusion to maintain a MAP >65mmHg or not to decrease by $>$ 30% from the baseline. The highest dose necessary was 0.12 µg/kg/min (Table 2).

Discussion

The main findings of the present study were that the incidence of hypotension, requiring vasopressor support, with this technique of fractional spinal anesthesia, was low. Furthermore, the hemodynamic aberrations after induction of fractional spinal anesthesia were minor, with a maximal fall in CI and MAP of 10-17%, 10 minutes after the first dose. After the second dose, no changes in hemodynamics were seen. Interestingly, the maximal fall in SVRI was 6% and appeared early after the first dose with no further fall after the second dose. Thus, the MAP reduction was less than expected and the major cause of this fall in MAP was a fall in CI, which explained almost 60% of the MAP reduction. This leads us to the conclusion that fractional spinal anesthesia, as described in the present study, induces a vasodilation

more prominent in systemic venous capacitance vessels, which decreases venous return and cardiac preload, as reflected by a decrease in SVI.

In this study, we defined hypotension as having a MAP <65mmHg or a drop of MAP more than 30% from the baseline level, a definition previously used in other studies[20][21]. Using this definition, the incidence of single-shot spinal anesthesia, has been described in previous studies to be 28-69%, which is considerably higher than noted in the present study[22, 23]. Thus, the use of fractional spinal anesthesia, as described here, may provide stable systemic hemodynamics in this elderly cohort of high-risk patients. Hypotension from a spinal anesthesia has been described by Butterworth[24] as a decrease in systemic vascular resistance and central venous pressure as a result of the sympathetic block, with vasodilatation of both systemic resistance vessels as well as venous capacitance vessels, the latter causing redistribution of central blood volume to the lower extremities and splanchnic beds and impaired venous return.

In the present study, MAP decreased by 17%, CI by 10%, SVRI by 6% and SVI by 7% 10 minutes after anesthesia induction. Our data imply that the MAP reduction is not easily explained by a reduction in SVRI alone. The proportionally larger fall in CI implicates vasodilation more on the venous capacitance vessels, leading to reduced venous return and subsequently a fall in CI and MAP. These findings are in line with the findings of Jakobsson et al, showing that a single shot of spinal anesthesia (15 mg bupivacaine) induced hypotension in 50% of the patients, mainly caused by a fall in CI (20%) and SVI (15%)[10]. Nakasuji et al, on the other hand, found that the hypotension seen after a single-shot spinal anesthesia (10 mg bupivacaine), in elderly patients, was mainly caused by systemic vasodilation and a fall in SVRI[9].

Our study cohort exhibited a significantly smaller fall in SVRI than described by Salinas et al[25], possibly due to lower dosing achieved with intermittent dosing and subsequently lower levels of sympathetic block. Effective arterial elastance (Ea) incorporates all elements of total LV afterload, including vascular resistance, arterial compliance and characteristic impedance[26]. The finding that Ea was not affected by fractional spinal anesthesia also indicates that the driving force of hypotension in the present study was systemic venodilation. We conclude that sympathetic blockade by fractional spinal anesthesia to a greater extent affects systemic capacitance vessels and that the fall in CI is driven by a corresponding fall in SVI, indicating a reduction in venous return.

Single shot neuraxial anesthesia is predominantly used around the world in in this population of patients. Dosages have decreased over time and in our clinical routine, we rarely administer more than 2.5 ml of mixtures of local anesthetics and opioids. The injection time the mixture is given may have an effect on the hypotension severity and we await studies addressing this topic. In an elegant study by Szucs et al[27] they used the method “up-and-down” described by Dixon and Massey in 1969 to find the lowest intrathecal dose of local anesthetic to provide adequate anesthesia for a hip fracture operation[28]. They concluded that 0.24 ml of 5 mg/ml isobaric bupivacaine was enough as a single dose but still recommended a dose of 0.4 ml or more i.e.2 mg. This is in concert with the present investigation where we gave dosages of 2.25 mg of isobaric bupivacaine although diluted to 1.5 mg/ml with

sodium chloride and fentanyl. The volume in this study was larger being 1.5 ml of the above-stated-solution. However, most clinician would not consider to administer such low doses with the eminent risk of blockade failure and forcing the attending anaesthesiologist to give general anaesthesia, an alternative considered worse at the preoperative evaluation.

An attractive alternative to single shot spinal is the continuous spinal anaesthesia (CSA) a technique described in the 1940´s[29] and improved by catheter insertion[30]. CSA has been associated with fewer incidents of hypotension per se and severer episodes of hypotension[31]. This led us to revisit the technique at our clinic as we have many hip fracture patients and many of them with aortic stenosis of variable severity[32, 33, 34]. We confirm the result of Minville et al that by carefully giving a CSA we can avoid severe hypotensive incidents even in frail patients. A side effect of this lower dosing was a less prominent motor blockage, also noted in the present investigation.

Although the hypotension found was less prominent, and was easily treated with low doses of vasoactive compounds, we wanted to investigate the hemodynamic origin of the moderate hypotension induced by fractionated spinal anesthesia. LiDCOplus is a semi-invasive, (needing an arterial catheter), validated method enabling us to register hemodynamic variables without the need for central venous- and/or Swan-Ganz catheters . The LiDCO system is therefore less invasive and does not require a higher degree of invasiveness than is routinely included in the normal clinical management of hip fracture patients at our hospital. The golden standard technique of measuring cardiac output is the use of a Swan-Ganz catheter, but this technique is hardly doable in a cohort of frail elderly hip fracture patients. Calibrated Cardiac output (CO) monitoring is easy and quick to start in patients already in need of arterial cannulation and provides a deeper insight into perioperative hemodynamic changes. In patients with a suspected aortic stenosis, the combination of spinal catheter and CO-monitoring could eliminate the need for preoperative ultrasound screening, minimizing risk of surgical delay. Further research into the role of uncalibrated CO monitoring and optimal dosing for intrathecal catheters is needed.

Limitation and strengths

With only 15 included patients the generalizability of our findings may be limited. We were restricted by the dynamic nature of running an effective emergency operating list, but also by the prevalence of patient anticoagulation therapy limiting the use of neuraxial anaesthesia in general and indwelling spinal catheter in particular. Haemodynamic monitoring with LiDCOplus gives us estimations of cardiac output after calibration, all other haemodynamic variables are derived from CO from the pulse power analysis and invasive blood pressure together with the heart rate[35]. A strength of our study is that the cohort was very homogenous with the similar age, fracture type and surgical procedure in a single tertiary orthopedic center.

Demographically our patients were older with elevated risk of higher mortality and morbidity versus the average hip fracture population (Table 1). All patients were included from the acute list and were all operated upon during office hours. Our university hospital is the largest orthopedic center in northern Europe and treat around 1000 patients with hip fracture yearly, thus 2-3 patients are operated

daily. The study population had a median age of 89 years and consisted primarily of women (80%).

Registry data of the Swedish hip fracture population demonstrates an average age of 82 and around 2/3 being female[1]. Thus, our patient cohort were 7 years older and thereby probably frailer than the average hip fracture patient. A surrogate marker for frailty in this investigation was ASA grading (mean value 3) and the NHFS score (mean value 5), both slightly elevated vs. the Swedish average[1]. Both scales assess comorbidity in various ways and are further used as prognostic scores for mortality risk in the perioperative and postoperative phase, like 30-day mortality[4, 5]. Therefore, we succeeded in finding a patient population with high comorbidly, speculatively having a higher risk for intraoperative hypotension than the average hip fracture population.

Conclusion

The initial blood pressure decline after fractional spinal anesthesia is caused mainly by systemic venodilation reducing venous return to the heart and then a fall in cardiac output. The incidence of hypotension was low and only one third of the patients needed norepinephrine infusions at modest doses, highest infusion rate was 0,12 µg/kg/min norepinephrine. Our results show that intermittent CSA-dosing is safe technique and probably underutilized in high-risk hip fracture patients.

Ethics approval and consent to participate

This study was approved by the central ethics committee in Uppsala, Sweden with approval number Dnr 2020-05684. The patients provided written consent. All methods were carried out in accordance with Declaration of Helsinki. Registred in clinicaltrials.gov (NCT05101291).

Funding

The study was funded by the Swedish State Support for Clinical Research (ALFGBG-75130) Västra Götaland, Sweden.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Abbreviations

AHF: Acute Hip Fracture; ASA: American Society of Anesthesiologists; NHFS: Nottingham Hip Fracture Score; CSA: Continous Spinal Anesthesia; MAP: Mean Arterial Pressure; CO: Cardiac Output; CI: Cardiac Index; SV: Stoke Volume; SVI: Stoke Volume Index; SVRI: Systemic Vascular Resistance Index; SAP: Systolic Arterial Pressure; DAP: Diastolic Arterial Pressure; EA: Effective Arterial Elastance; BSA: Body Surface Area

Competing interests

The authors declare that they have no competing interests.

Author's contributions

FO: Planned and designed the study. Established intrathecal catheter and set up LidCo monitoring, collected and analyzed data. Wrote the first draft. MHaS: Planned and designed the study and revised the manuscript. KD: Revised the manuscript. SER: Planned and designed the study and revised the manuscript. BN: Planned and designed the study and revised the manuscript. All authors read and approved the final manuscript.

Acknowledgements

The authors wish to acknowledge the nursing staff and fellow anesthesiologists at Mölndal University Hospital for their assistance.

Authors' information

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Figures

Tables

Figures

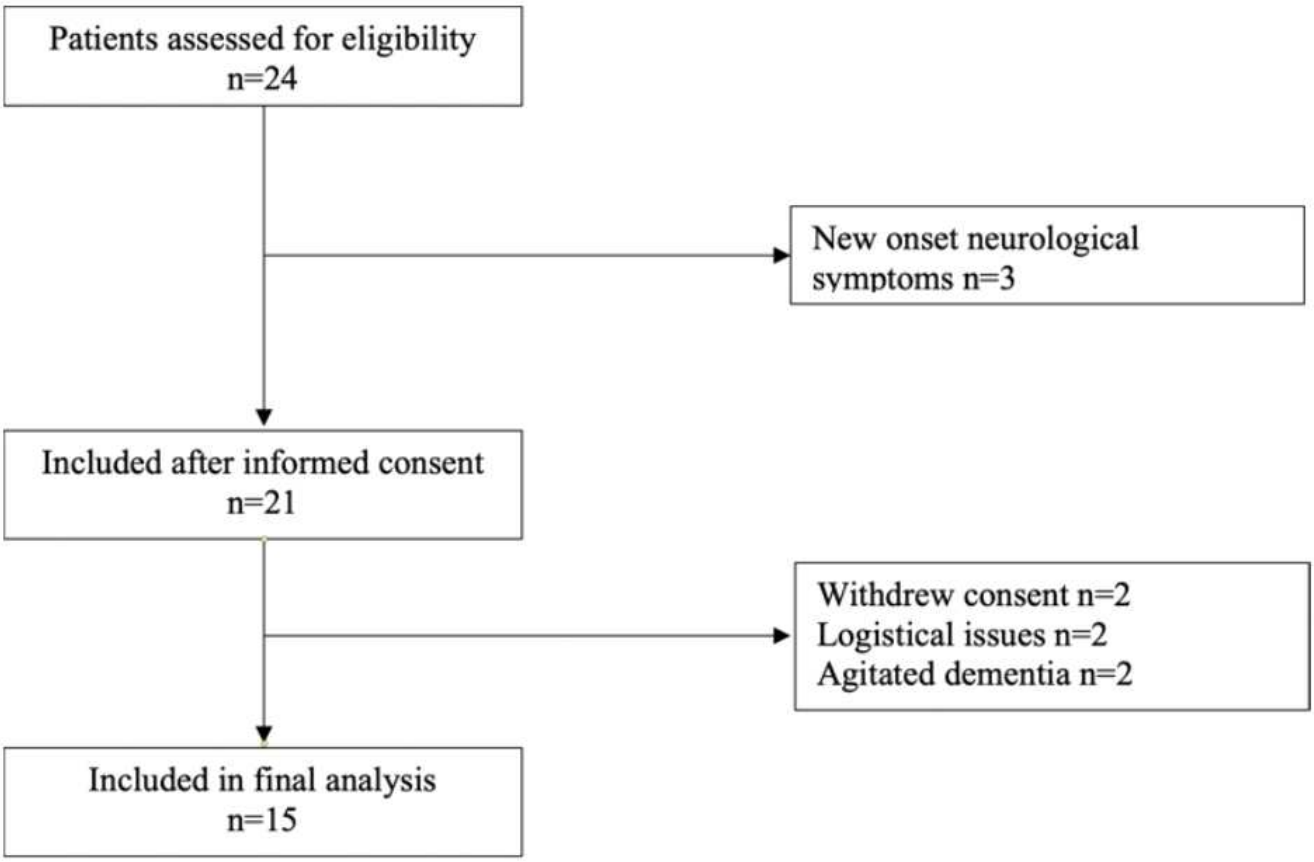

Figure 1

Consort diagram

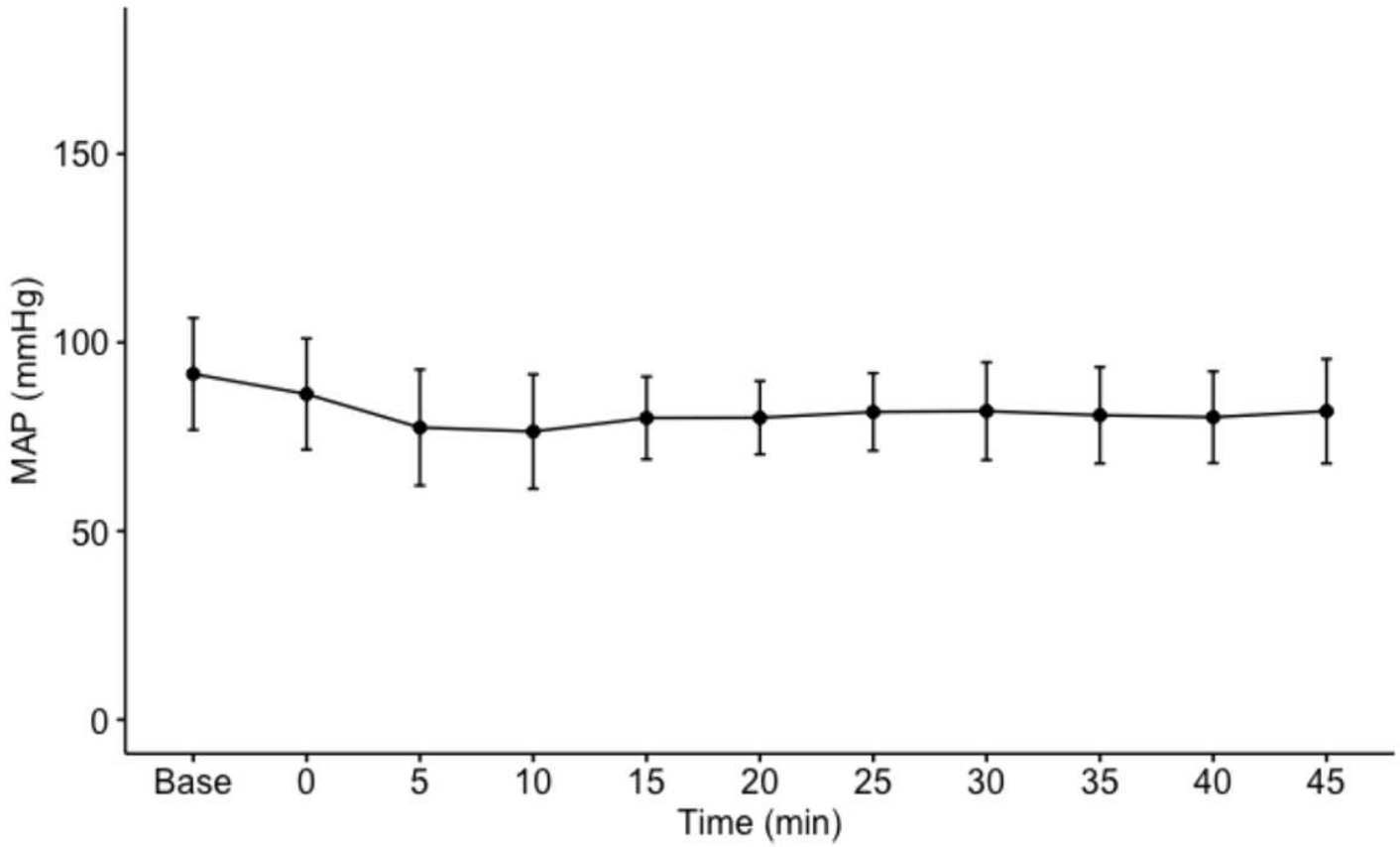

Figure 2

Changes in mean arterial pressure over time (mean ±1SD)

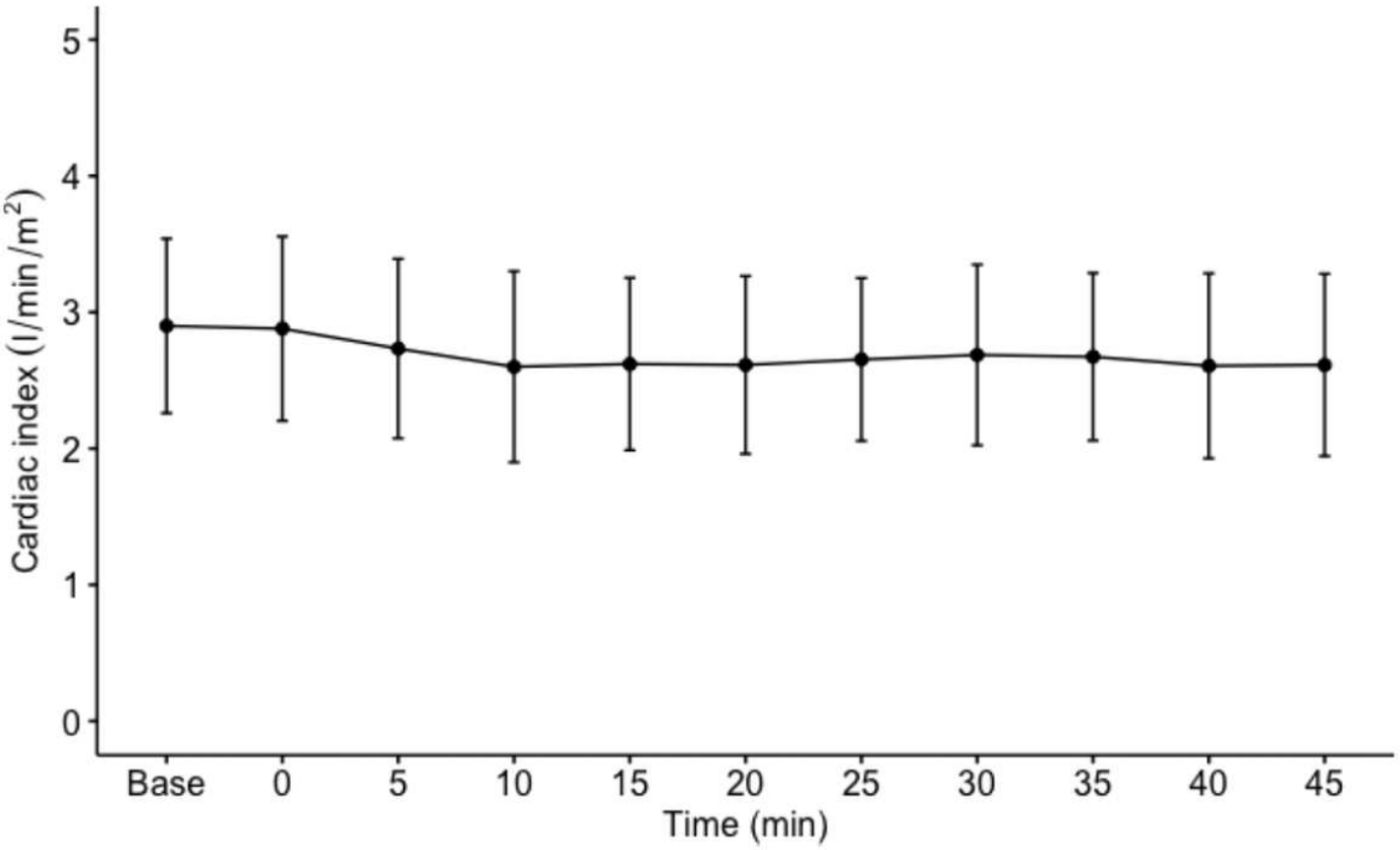

Figure 3

Changes in cardiac index over time (mean ±1SD)

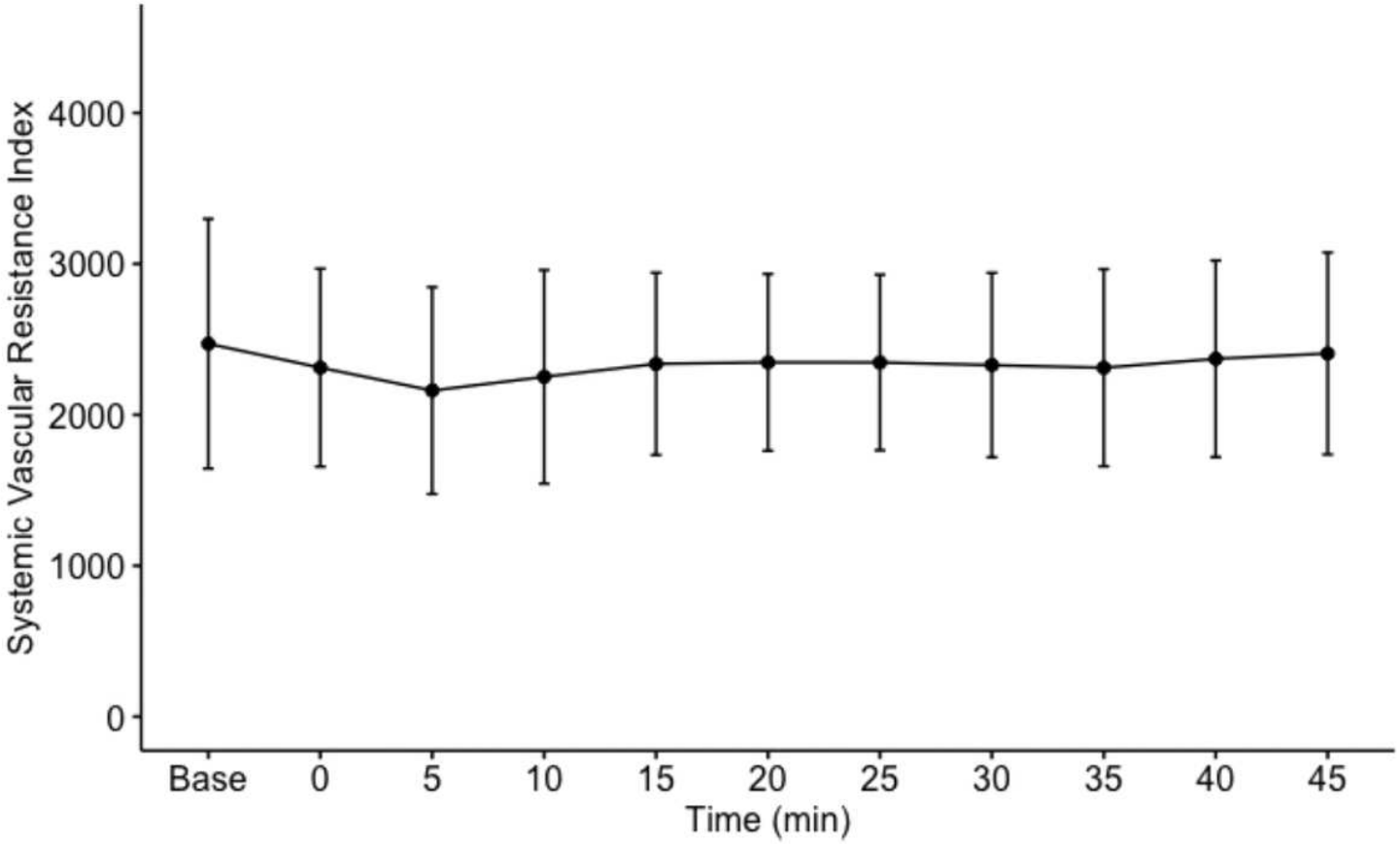

Figure 4

Changes in systemic vascular resistance over time (mean ±1SD)

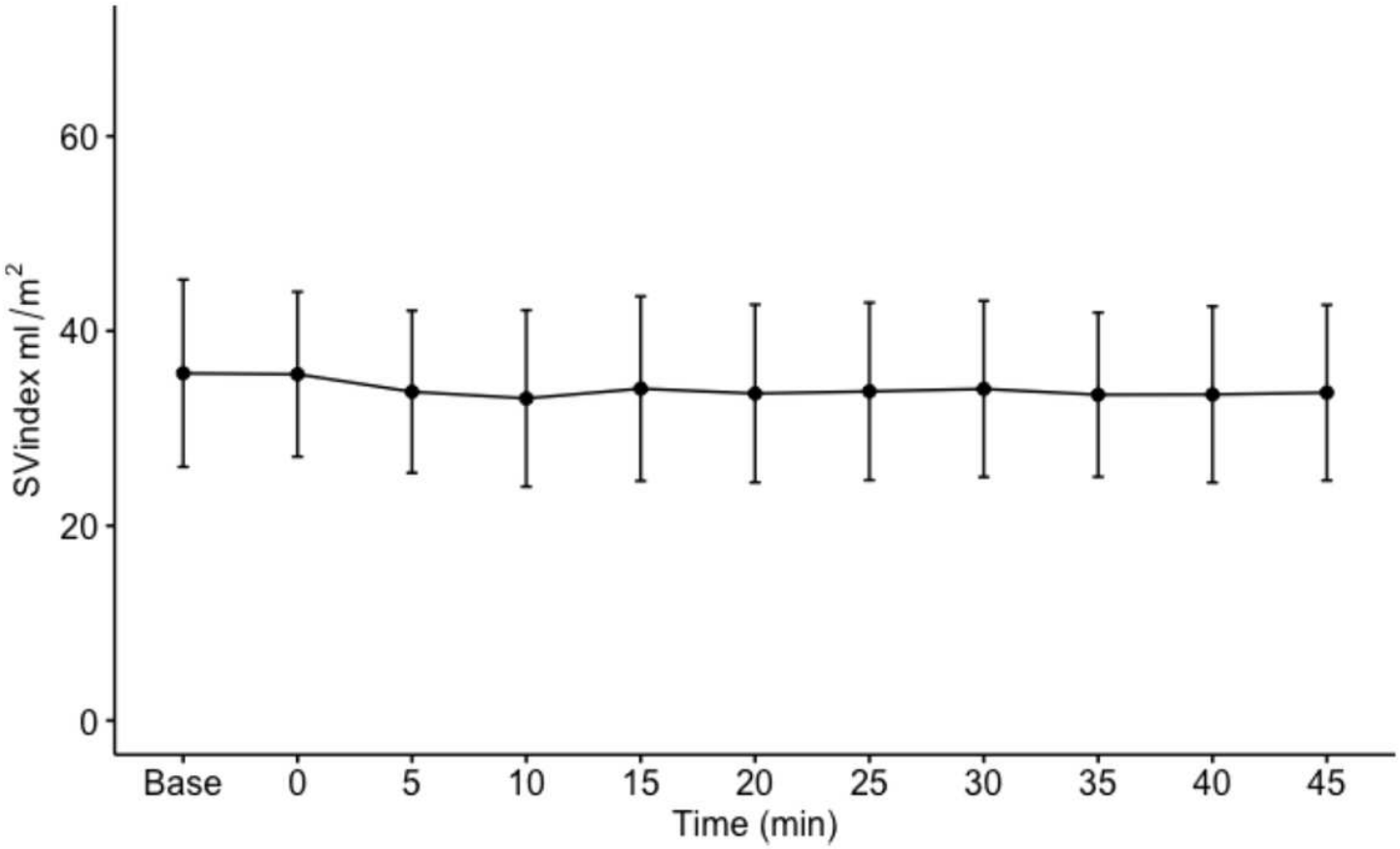

Figure 5

Changes in in stroke volume index (SVI) over time (mean ±1SD)

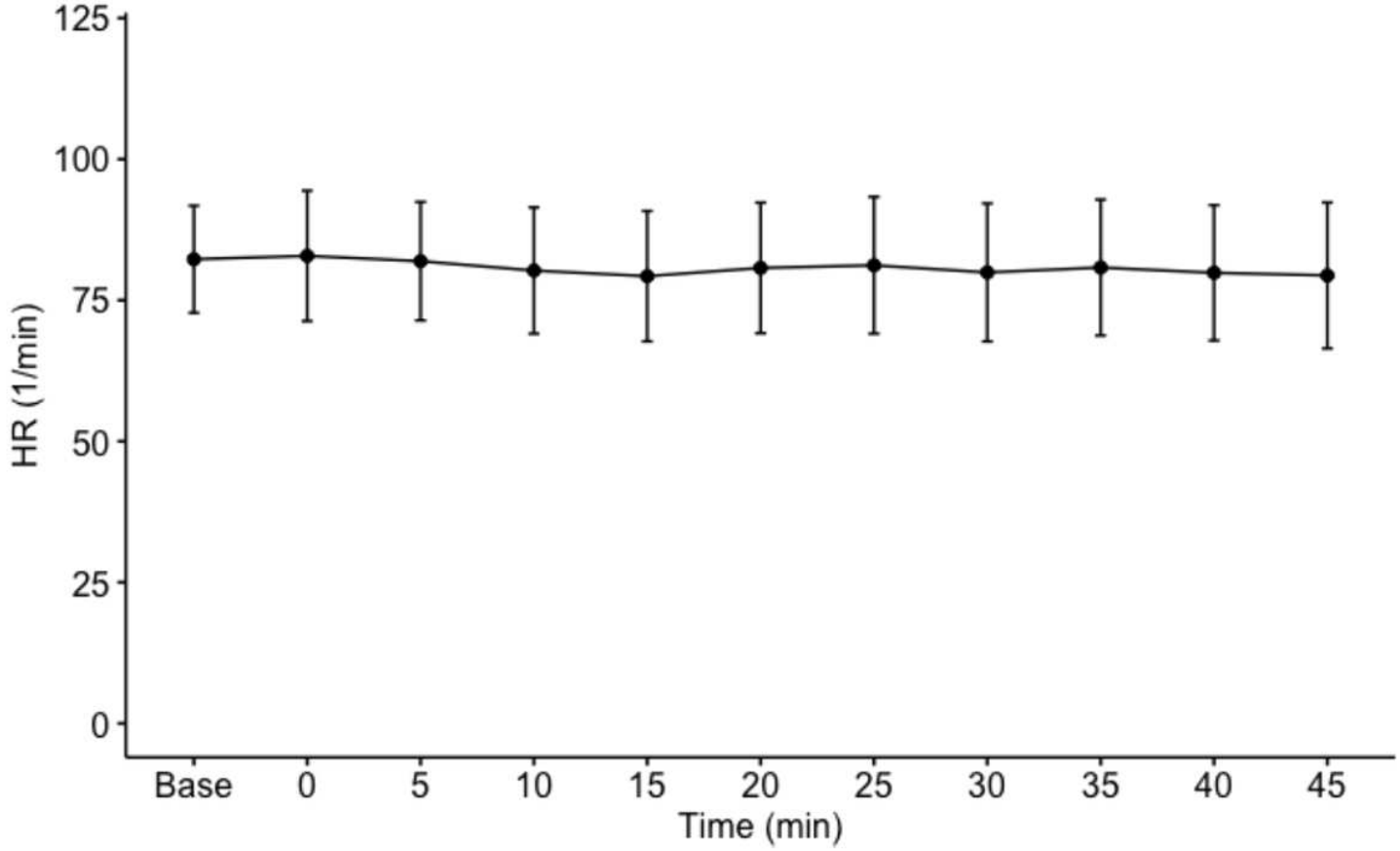

Figure 6

Changes in heart rate (HR) over time (mean ±1SD)

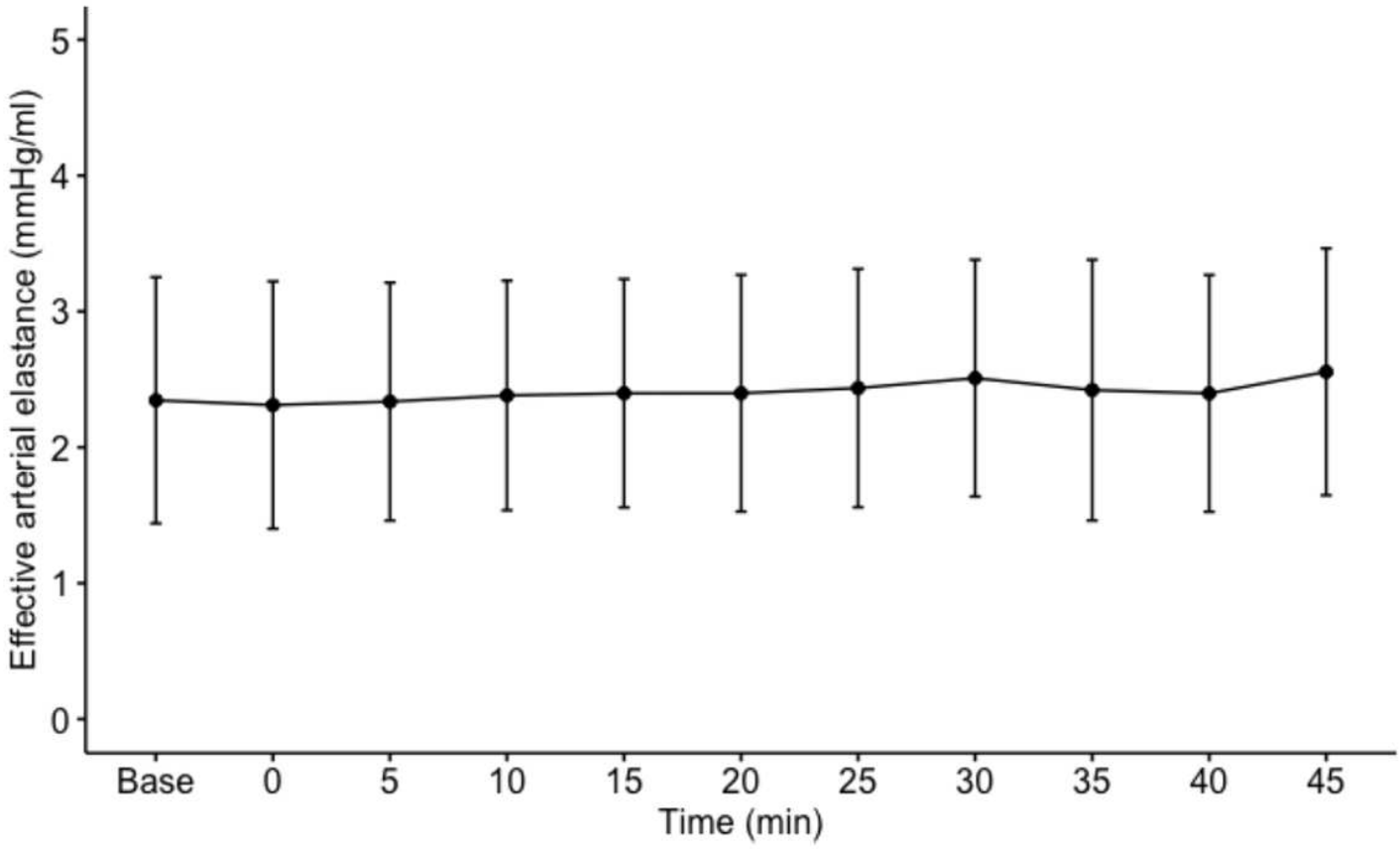

Figure 7

Changes in arterial elastance over time (mean ±1SD)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- tbl1.pdf
- tbl2.pdf