Remote ischaemic preconditioning influences the levels of acylcarnitines in vascular surgery: a randomised clinical trial

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Abstract

Background Vascular surgery affects tissues` blood supply and microcirculation and might lead to mitochondrial dysfunction, which may result in the accumulation of acylcarnitines (ACs). It has been suggested that remote ischaemic preconditioning (RIPC) has its organ protective effect via promoting mitochondrial function. The aim of this study was to evaluate the effect of RIPC on the profile of ACs in the vascular surgery patients.

Methods. This is a randomised, sham-controlled, double-blinded, single-centre study. Patients undergoing open abdominal aortic aneurysm repair, surgical lower limb revascularisation surgery or carotid endarterectomy were recruited non-consecutively. The RIPC protocol consisting of 4 cycles of 5 minutes of ischaemia, followed by 5 minutes of reperfusion, was applied. A blood pressure cuff was used for RIPC or a sham procedure. Blood was collected preoperatively and approximately 24 hours postoperatively. The profile of ACs was analysed using the AbsoluteIDQp180 kit (Biocrates Life Sciences AG, Innsbruck, Austria).

Results Ninety-eight patients were recruited and randomised into the study groups and 45 patients from the RIPC group and 47 patients from the sham group were included in final analysis. There was a statistically significant difference between the groups regarding the changes in C3-OH (p=0.023) - there was a significant decrease (-0.007 μmol/L, ± 0.020 μmol/L, p=0.0233) in the RIPC group and insignificant increase (0.002 μmol/L, ±0.015 μmol/L, p=0.481) in the sham group. Additionally, a statistically significant decrease (p<0.05) was detected both in the sham and the RIPC group in the levels of following ACs: C2, C8, C10, C10:1, C12, C12:1, C14:1, C14:2, C16, C16:1, C18, C18:1, C18:2. In the sham group, there was a statistically significant increase (p<0.05) in the levels of C0 (carnitine) and a statistically significant decrease in the level of C18:1-OH. In the RIPC group, a statistically significant decrease (p<0.05) was noted in the levels of C3-OH, C3-DC (C4-OH), C6:1, C9, C10:2.

Conclusions It can be concluded that RIPC has an effect on the levels of ACs and can therefore have protective effects on mitochondria in the vascular surgery patients. Further studies conducted on metabolically more homogenous populations are needed to make more definite conclusions about the effect of RIPC on the levels of ACs.

Trial registration: ClinicalTrials.gov database, NCT02689414. Registered 24 February 2016 - Retrospectively registered, https://clinicaltrials.gov/ct2/show/NCT02689414.

Background

Remote ischaemic preconditioning (RIPC) is an experimental procedure in which short episodes of ischaemia are induced in order to offer organ protection to distant tissues. We along other investigators have demonstrated that RIPC has protective effects to heart, kidneys, brain and other organs in the case of ischaemia-reperfusion injury [1–5]. The exact mechanisms of RIPC are not known, but during the last decade multiple pathways and biochemical markers involved in achieving the effect of RIPC have been

discovered involved in achieving RIPC effect. It has been found that cardioprotection by RIPC occurs along with improved mitochondrial function in animal studies [6, 7]. As ischaemia-reperfusion injury is known to impair mitochondrial function, the effect of RIPC might be beneficial in reducing the extent of injury. Ischaemia-reperfusion injury is inevitable in vascular surgery. Also, surgery induces acute stress response, which in turn promotes catabolic pathways including fatty-acid catabolism in beta-oxidation hereby increasing the load on mitochondria even more. Mitochondria have a principal position in energy metabolism and intensification of the beta-oxidation of fatty acids in mitochondria leads to elevated ATP production due to integrated action of the Krebs cycle and the respiratory chain. In the case of mitochondrial dysfunction, fatty acid β-oxidation is diminished, resulting in accumulation of acylcarnitines (ACs) [8, 9]. ACs are esters of L-carnitine and fatty acids and due to existence of different fatty acids [10], a large set of ACs can be produced that are generally divided into short, medium and long chain ACs (denoted as SCACs, MCACs and LCACs). For transport of fatty acid into mitochondria for beta-oxidation, the coenzyme A group is attached and afterwards displaced by carnitine forming an acylcarnitine, which is able to enter the mitochondrial matrix where it can be broken down by carnitine palmitoyl transferase II to release activated fatty acid to enter beta-oxidation [11]. It is crucial to produce LCACs as mitochondrial inner membrane is impenetrable for long chain fatty acids. Because of this, the increase of LCACs is most commonly associated with metabolic disorders such as mitochondrial dysfunction and genetic enzyme deficiencies [11]. However, as more knowledge has been gained about the role of SCACs and MCACs, it is necessary to simultaneously investigate changes of SCACs, MCACs and LCACs.

Considering all this, shifts in the ACs profile might occur in response to RIPC in patients undergoing vascular surgery. To our knowledge, no studies have been published about the effect of RIPC on the whole profile (C2-C18) of ACs.

This is a substudy within our large clinical trial conducted for evaluating the effect of RIPC on arterial stiffness and end-organ damage [1, 2, 12]. Among our secondary aims was to investigate changes in the levels of ACs. We hypothesised that RIPC may prevent the increase of the levels of ACs, ensuing from metabolic shifts in patients undergoing vascular surgery and the aim of the current study was to test this hypothesis.

Methods

Study groups and eligibility

This randomised double-blinded sham-controlled clinical trial was conducted at the Department of Vascular Surgery, Clinic of Surgery, at Tartu University Hospital.

Patients undergoing open infra-renal abdominal aortic aneurysm (AAA) repair or surgical lower limb revascularisation surgery (for claudication or critical limb ischaemia; common femoral artery endarterectomy, aorto(bi)femoral or femoropopliteal or femorotibial or iliofemoral bypass surgery) or

carotid endarterectomy (for symptomatic or asymptomatic carotid stenosis) during the period from January 1, 2016 to February 8, 2018 were recruited non-consecutively.

Signed informed consent was obtained from each patient.

The research protocol of our study was approved by the Research Ethics Committee of the University of Tartu, and was registered in the ClinicalTrials.gov database (NCT02689414).

The following exclusion criteria were applied: age under 18 years, pregnancy, known malignancy in the past 5 years, permanent atrial fibrillation or flutter, symptomatic upper limb atherosclerosis, need for oxygen therapy at home, estimated preoperative glomerular filtration rate (eGFR) < 30 ml/min/1.73 m^2, myocardial infarction in the past month, previous history of upper limb vein thrombosis or vascular surgery in the axillary region, and inability to follow the study regimen.

Intervention

The RIPC protocol consisted of four 5-minute episodes of ischaemia with a 5-minute period of reperfusion between the episodes, which has been one of the most often used protocols in earlier studies. Ischaemia was achieved by placing a blood pressure cuff on an arm and raising cuff pressure to 200 mm Hg. In case the patient's blood pressure exceeded 180 mm Hg, the cuff pressure was raised to a value that was 20 mm Hg higher than systolic blood pressure. For sham group patients, cuff pressure was kept at level of venous pressure (10–20 mm Hg). Intervention began along with preparation for anaesthesia in the operating theatre. Any other aspects of surgery, including anaesthesia and medication use, were not affected. The principal investigator was in charge of patient recruitment, assignment to intervention and data storage.

Blinding

The patient, patient's physician, surgeon, anaesthesiologist and everyone else in the surgical team were blinded to study intervention. The scale of the manometer was kept covered. The statistician was blinded to the meaning of the group affiliation.

Outcomes

Blood samples for analysis of ACs were collected in the morning of surgery and approximately 24 hours after surgery. The last blood collection was set as close as possible to 24 hours after surgery on condition that the patient had fasted for at least 3 hours. Blood samples were centrifuged, serum was separated and stored in the refrigerator at -80 °C.

The levels of ACs were analysed using the AbsoluteIDQp180 kit (Biocrates Life Sciences AG, Innsbruck, Austria). The analytical procedure was performed according to the manufacturer's standard protocol in the laboratory of the Department of Biochemistry, University of Tartu. In brief, for targeted analysis of metabolites internal standard was pipetted onto a 96-well extraction plate and 10 µl serum was added to each well. Drainage was achieved with nitrogen and derivatisation was performed with

phenylisothiocyanate. The measurements were accomplished with QTRAP 4500 (ABSciex, USA) coupled to an Agilent 1260 series HPLC (USA), using the C18 column and flow injection analysis. The vendor's software with internal standards' intensities was used to calculate the concentrations of ACs along with other metabolites, which are not discussed in this paper.

Blood samples for analysis of high sensitivity troponin T (hs-TnT) and N-terminal pro-brain natriuretic peptide (NT-proBNP) which were used to calculate correlations, were collected along with the samples for analysis of ACs preoperatively and approximately 24 hours after surgery. The levels of cardiac biomarkers were analysed at the United Laboratories of Tartu University Hospital.

All patients were asked about their previous and current health issues and medications; an electronic health database was also used for complete anamnesis.

Statistical analysis

Two groups were compared using Student's t-test or the Wilcoxon rank-sum or Chi-squared test as appropriate. For assessing correlations between changes in the levels of AC and cardiac biomarkers, Spearman's correlation coefficient was employed.

P-values under 0.05 were considered significant. Statistical analysis was performed by a qualified statistician from the University of Tartu.

As the study's primary outcomes were parameters of arterial stiffness, calculation of sample size was based on their values [12]. For both groups, calculated sample size was 44.

Results

Ninety-eight patients were recruited and randomised into the study groups and 45 patients from the RIPC group and 47 patients from the sham group were included in final analysis.

Detailed patient flow is depicted in Fig. 1. The median time from the end of intervention to the beginning of surgery did not differ significantly ($p = 0.057$) between the RIPC (36 min, IQR 21—46 min) and the sham group (25 min, IQR 15—38 min). The baseline characteristics of the two groups were similar (Table 1). No adverse events due to RIPC were described and no patient found the RIPC or the sham procedure unbearable.

Changes in the levels of ACs in the RIPC and in the sham group (Table 2)

A statistically significant decrease ($p < 0.05$) was detected both in the sham and the RIPC group in the levels of following ACs: C2, C8, C10, C10:1, C12, C12:1, C14:1, C14:2, C16, C16:1, C18, C18:1, C18:2. In the sham group, there was a statistically significant increase ($p < 0.05$) in the levels of C0 (carnitine) and a

statistically significant decrease in the level of C18:1-OH. In the RIPC group, a statistically significant decrease (p < 0.05) was noted in the levels of C3-OH, C3-DC (C4-OH), C6:1, C9, C10:2. There was a statistically significant difference between the groups regarding the changes in C3-OH (p = 0.023) - there was a significant decrease (-0.007 μmol/L, ± 0.020 μmol/L, p = 0.0233) in the RIPC group and insignificant increase (0.002 μmol/L, ± 0.015 μmol/L, p = 0.481) in the sham group.

Correlations between change in hs-TnT and changes in the levels of ACs (Table 3)

In the RIPC group, there were statistically significant positive correlations between change of hs-TnT and change of C4 (cor = 0.38, p = 0.01), C10 (cor = 0.38, p = 0.010), C10:1 (cor = 0.38, p = 0.010), C12:1 (cor = 0.31, p = 0.037), C18:1 (cor = 0.32, p = 0.030) and C18-OH (cor = 0.35, p = 0.019). In the sham group, there was statistically significant negative correlation between change of hs-TnT and change of C5-OH (cor= -0.34, p = 0.021). No other significant correlations were observed between changes in the levels of hs-TnT and ACs in the sham group.

Correlations between change in NT-proBNP and changes in the levels of ACs (Table 3)

In the RIPC group a statistically significant positive correlation occurred between change of NT-proBNP and change of C16:2 (cor = 0.34, p = 0.021). In the sham group, a statistically significant positive correlation occurred between change of NT-proBNP and change of C18 (cor = 0.31, p = 0.031) and statistically significant negative correlation between change of NT-proBNP and change of C16:1 (cor= -0.35, p = 0.016)

Discussion

There have been no studies evaluating the effect of RIPC on the level of carnitine (C0) and on the profile of all acylcarnitines (C2-C18). In this study we describe the positive effect of RIPC in lowering the levels of several ACs in patients undergoing vascular surgery. There was a statistically significant increase in the levels of C0 in the sham group, no significant increase occurred in the levels of any ACs but a statistically significant decrease occurred in the levels of C3, C3-OH, C3-DC (C4-OH), C4, C5, C6:1, C9, C10:2 in the RIPC group. In addition, we noted a statistically significant difference in the level of C3-OH between the groups. All these findings indicate the RIPC-directed effect on the ACs profile in plasma.

Based on previous studies, the decrease in the levels of ACs can be associated with preserved mitochondrial function [9] whereas their increase has been linked to increased mortality in chronic heart failure patients [8] and worse prognosis in patients with IgA nephropathy [13]. Several carnitine esters and members of the ACs are elevated in patients with peripheral artery disease (PAD) [14]. Nevertheless, the impact of ACs in clinical practice is unknown as relevant studies are lacking. Considering the results of

the studies published about ACs, knowledge of the ACs profile may facilitate assessment of the patients' general metabolic milieu, mitochondrial functioning and prognosis.

ACs have a different origin in plasma. The main precursors of SCACs are branched chain amino acids (BCAAs) but some SCASs are also produced by catabolism of glucose and some triglycerides. MCACs and LCACS are only derived from fatty acid metabolism whereas carnitine is required for transporting long-chain fatty acids into mitochondria [15]. Hence plasma ACs does not exactly reflect whole-body acylcarnitine metabolism [16], but it allows to make some conclusions about metabolism in some organs. SCASs in plasma has been found to be released from the liver [16], MCACs, from the skeletal muscles and liver [17] and LCACs, from the heart [15]. It should be noted that the hepatoprotective effect of RIPC has been reported previously [4, 18]. We observed an increase of some SCACs levels in the sham group whereas no any increase of ACs occurred in the RIPC group.

Evidently, the stress caused by surgery enhances the catabolism of BCCA in the liver in order to produce additional metabolic energy and this is accompanied by an increase of plasma SCACs. RIPC has been found to intensify hepatic oxygenation and hepatic microcirculation via activation of eNOS [19], as well as to increase expression of protector proteins (e.g. heme oxygenase 1) [20], which preserves mitochondrial functionality. Hence, produced SCACs can be spent more efficiently in the case of RIPC and, based on our findings we could suppose that RIPC might have a protective effect on the liver. Surgery increases the demand for metabolic energy may also cause elevated level of ketone bodies leading to production of C3-OH. In RIPC, the elimination of this SCAC is more effective compared to the sham group, which results in a statistically significant difference between these groups.

As a response to any surgery, the human organism intensifies the production of metabolic energy, which is accompanied by additional spending of long chain fatty acids for energy-rich substrates through LCACs. This can explain for the decline in LCASs both in the sham and the RIPC group.

The cardioprotective effect of RIPC has been studied on humans since 2006 [21], however, results are contradictory. Although a previously published systematic review on patients undergoing non-cardiac vascular surgery reports no effect of RIPC in reducing myocardial injury [22], its cardioprotective effect has been described in more homogenous and more powerful studies with other populations. Cardioprotection by RIPC has been associated with the improved function of mitochondria [23–25]. However, two of these studies failed to demonstrate an effect of RIPC on cardioprotection and hence also correlation between cardioprotection and salvage of mitochondrial function [23, 24].

Previously, we have published a study on the same cohort, where we demonstrated positive effects of RIPC in reducing the levels of hsTnT and NT-proBNP [26]. In the present study, we describe positive correlations between decrease of these cardiac biomarkers and decrease of several ACs in the RIPC group. In the sham group, no positive correlations were noted between increase of hsTnT and increase of ACs. On the contrary, there was negative correlation between increase of hsTnT and increase of C5-OH. Also there was a negative correlation between increase of NT-proBNP and C16:2 and positive correlation between increase of NT-proBNP and C18. Although the above correlations were not significant, these

differences between the sham and the RIPC group and the previously described cardioprotective effects of RIPC in the same cohort [26] suggest that the cardioprotective effects could be described basing on shifts in the levels of ACs. However, further studies are needed to clarify these assumptions.

There are several limitations to our study. Firstly, the study population was heterogeneous as was also presumably their metabolic status. It has been found that the levels of ACs differ among patients with different stages of PAD those without PAD [14]. As in our study there were patients with different locations and stages of atherosclerotic lesions, their metabolic status was evidently different, which may have influenced the results. Also we recruited both diabetic and non-diabetic patients in our groups and diabetes has been found to affect the levels of ACs [27] and have a deleterious effect on RIPC [28, 29]. Moreover, the patients underwent different types of surgery and the extent of tissue damage was different. The AAA patients undergoing open aortic aneurysm repair probably experienced larger tissue damage and were not chronically preconditioned against ischaemia like might have been PAD patients who were undergoing peripheral artery revascularisation surgery. Thus the type of surgery may have had a great impact on the metabolism of ACs and the effect of RIPC may have been overwhelmed. In addition, in 42% of the patients in the RIPC group propofol-induced anaesthesia was used and propofol has been found to reduce the effect of RIPC [30]. Also, the size of the study group was relatively small and the true effect of RIPC might have been missed as there were multiple differences between the groups, which did not quite reach statistical significance.

Conclusions

It can be concluded that RIPC has an effect on the levels of ACs and can therefore have protective effects on mitochondria in the vascular surgery patients. Further studies conducted on metabolically more homogenous populations are needed to make more definite conclusions about the effect of RIPC on the levels of ACs.

Abbreviations

AAA - abdominal aortic aneurysm

ACs – acylcarnitines

LCACs – long chain acylcarnitines

MSCASs – medium chain acylcarnitines

PAD – peripheral artery disease

RIPC – remote ischaemic preconditioning

SCASc – short chain acylcarnitines

Declarations

Ethics approval and consent to participate

Signed informed consent was obtained from each patient. The research protocol of our study was approved by the Research Ethics Committee of the University of Tartu (protocol's number: 252/M-24).

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.

Competing interests

The authors declare that they have no competing interests

Authors' contributions

TK, KK, UL, JS, MZ, JE and JK contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. TK was the main contributor in writing the manuscript. JK conceived the original idea. MV performed the statistical analysis. All authors read and approved the final manuscript.

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Tables

Table 1 Baseline characteristics.

Variable	RIPC (n=45)	SHAM (n=47)	p-value
Age, years (SD)	67 (±9)	66 (±10)	0.577
Male, n (%)	36 (80)	32 (68)	0.288
BMI, kg/m2 (SD)	26.3 (±6.4)	26.5 (±6.7)	0.840
ASA 2, n (%)	18 (40)	19 (40)	1
ASA 3, n (%)	20 (44)	22 (47)	0.986
ASA 4, n (%)	7 (16)	6 (13)	0.933
ACEI or ARB, n (%)	21 (47)	30 (64)	0.148
Calcium channel blockers, n (%)	9 (20)	17 (37)	0.135
Beta-blockers, n (%)	11 (24)	19 (40)	0.158
Statins, n (%)	13 (29)	14 (30)	1
Diabetes, n (%)	5 (11)	8 (17)	0.607
Myocardial infarction, n (%)	8 (18)	3 (6)	0.172
Stroke, n (%)	10 (22)	12 (26)	0.899
Smoker (current or ex-smoker), n (%)	40 (89)	42 (89)	1
MAP, mm Hg (SD)	99 (±12)	100 (±11)	0.678
Heart rate, bpm (SD)	66 (±9)	67 (±11)	0.754
Cholesterol, mmol/L (IQR)	5.0 (4.2–5.7)	5.0 (3.9–5.6)	0.793
LDL, mmol/L (IQR)	3.4 (8.1–10.4)	3.3 (2.5–3.8)	0.500
HDL, mmol/L (IQR)	1.1 (0.9–1.4)	1.1 (1.0–1.3)	0.311
Triglycerides, mmol/L (IQR)	1.6 (1.3–1.8)	1.5 (1.2–2.0)	0.787
Administration of propofol, n (%)	19 (42)	26 (55)	0.295
Duration of surgery, min (IQR)	108 (89–135)	112 (84–156)	0.827

BMI – body mass index; ASA – American Society of Anaesthesiologists' physical status score; ACEI – angiotensin-converting-enzyme inhibitor; ARB – angiotensin II receptor blocker; PSBP – peripheral systolic blood pressure; PDBP – peripheral diastolic blood pressure; CSBP – central systolic blood pressure; CDBP – central diastolic blood pressure; MAP – mean arterial blood pressure; SD – standard deviation; IQR – interquartile range

Table 2 Changes in the levels of acylcarnitine esters from baseline to 24 hours postoperatively. Data are shown as mean change ± standard deviation. Statistically significant p-values are in **bold.**

| | SHAM | | RIPC | | RIPC vs SHAM |
	Change (μmol/L)	p-value	Change (μmol/L)	p-value	p-value
C0	5.094 (±14.137)	**0.0173**	4.211 (±14.795)	0.0628	0.7057
C2	-1.137 (±3.082)	**0.0149**	-1.258 (±2.862)	**0.0051**	0.7912
C3	0.011 (±0.313)	**<0.0001**	-0.078 (±0.385)	**<0.0001**	0.2428
C3-DC	-0.003 (±0.026)	0.3944	-0.008 (±0.027)	**0.0488**	0.7231
C3-OH	0.002 (±0.015)	0.4809	-0.007 (±0.02)0	**0.0233**	**0.0232**
C3:1	-0.000 (±0.015)	0.9557	-0.002 (±0.017)	0.4578	0.6078
C4	0.017 (±0.111)	**<0.0001**	-0.013 (±0.117)	**<0.0001**	0.2042
C4:1	0.002 (±0.015)	0.2679	-0.003 (±0.018)	0.2227	0.0976
C5	0.004 (±0.116)	**<0.0001**	-0.037 (±0.153)	**<0.0001**	*0.0553*
C5-DC (C6-OH)	0.001 (±0.030)	0.8467	0.003 (±0.024)	0.4274	0.7236
C5-M-DC	0.011 (±0.036)	0.0504	0.008 (±0.039)	0.1865	0.3989
C5-OH (C3-DC-M)	-0.002 (±0.016)	0.4681	-0.003 (±0.018)	0.3501	0.6769
C5:1	0.001 (±0.014)	0.7822	-0.004 (±0.022)	0.2437	*0.0583*
C5:1-DC	0.003 (±0.014)	0.0931	-0.002 (±0.016)	0.5304	0.1824
C6 (C4:1-DC)	-0.007 (±0.040)	0.2417	-0.008 (±0.042)	0.2027	0.7639
C6:1	-0.000 (±0.001)	0.8706	-0.001 (±0.002)	**0.0482**	0.1071

	SHAM		RIPC		RIPC vs SHAM
	Change (µmol/L)	p-value	Change (µmol/L)	p-value	p-value
C7-DC	-0.002 (±0.012)	0.1833	-0.002 (±0.011)	0.2147	0.9025
C8	-0.053 (±0.109)	**0.0017**	-0.052 (±0.085)	**0.0002**	0.9658
C9	0.000 (±0.019)	0.8637	-0.008 (±0.021)	**0.0230**	*0.0590*
C10	-0.103 (±0.166)	**<0.0001**	-0.115 (±0.183)	**<0.0001**	0.9348
C10:1	-0.030 (±0.054)	**0.0005**	-0.033 (±0.043)	**<0.0001**	0.6856
C10:2	-0.002 (±0.021)	0.4419	-0.009 (±0.021)	**0.0074**	0.1454
C12	-0.026 (±0.062)	**<0.0001**	-0.026 (±0.048)	**<0.0001**	0.8395
C12-DC	-0.007 (±0.026)	0.0699	0.000 (±0.027)	0.9137	0.1800
C12:1	-0.024 (±0.050)	**0.0015**	-0.033 (±0.034)	**<0.0001**	0.2160
C14	-0.005 (±0.023)	**<0.0001**	-0.002 (±0.032)	**<0.0001**	0.9039
C14:1	-0.026 (±0.046)	**<0.0001**	-0.022 (±0.027)	**<0.0001**	0.9379
C14:1-OH	0.000 (±0.010)	0.8262	-0.001 (±0.011)	0.5096	0.5179
C14:2	-0.011 (±0.015)	**<0.0001**	-0.007 (±0.014)	**0.0018**	0.1529
C14:2-OH	-0.000 (±0.022)	0.9380	0.002 (±0.013)	0.2544	0.9720
C16	-0.036 (±0.040)	**<0.0001**	-0.029 (±0.035)	**<0.0001**	0.3668
C16-OH	-0.002 (±0.012)	0.3247	-0.003 (±0.017)	0.2893	0.7603

	SHAM		RIPC		RIPC vs SHAM
	Change (µmol/L)	p-value	Change (µmol/L)	p-value	p-value
C16:1	-0.012 (±0.018)	**<0.0001**	-0.010 (±0.017)	**0.0003**	0.6482
C16:1-OH	-0.003 (±0.009)	0.0542	-0.003 (±0.011)	0.0718	0.8257
C16:2	-0.003 (±0.018)	0.3098	-0.002 (±0.017)	0.4121	0.9348
C16:2-OH	-0.001 (±0.008)	0.4349	-0.000 (±0.009)	0.8756	0.8915
C18	-0.494 (±0.787)	**<0.0001**	-0.619 (±0.990)	**<0.0001**	0.8032
C18:1	-0.057 (±0.051)	**<0.0001**	-0.050 (±0.043)	**<0.0001**	0.4525
C18:1-OH	-0.006 (±0.014)	**0.0045**	-0.000 (±0.016)	0.9242	0.0980
C18:2	-0.015 (±0.015)	**<0.0001**	-0.018 (±0.016)	**<0.0001**	0.4541

Table 3 Substantial correlations between cardiac biomarkers (i.e. high sensitivity troponin T and NT-proBNP) and acylcarnitines. Statistically significant p-values and correlations are in bold

|	Hs-TnT				NT-proBNP			
	RIPC (n=45)	p-value	SHAM (n=47)	p-value	RIPC (n=45)	p*	SHAM (n=47)	p-value
C4	**0.38**	**0.01**	-0.05	0.734	0.10	0.532	-0.26	0.081
C5-DC	0.18	0.230	-0.29	0.050	0.15	0.320	-0.16	0.276
C5-OH	0.13	0.379	**-0.34**	**0.021**	-0.06	0.719	0.14	0.359
C7-DC	0.07	0.639	-0.08	0.580	0.18	0.241	0.28	0.055
C10	**0.38**	**0.010**	-0.12	0.416	0.30	0.049	-0.10	0.519
C10:1	**0.38**	**0.010**	-0.12	0.404	0.18	0.225	-0.12	0.405
C12:1	**0.31**	**0.037**	-0.06	0.672	0.18	0.232	-0.04	0.797
C16:1	-0.15	0.341	-0.25	0.090	0.10	0.500	**-0.35**	**0.016**
C16:2	0.10	0.494	-0.12	0.407	**0.34**	**0.021**	0.O6	0.688
C18	0.05	0.745	-0.11	0.476	0.17	0.268	**0.31**	**0.031**
C18:1	**0.32**	**0.030**	-0.15	0.300	0.15	0.329	-0.13	0.389
C18-OH	**0.35**	**0.019**	-0.07	0.628	0.12	0.431	-0.27	0.07

Figures
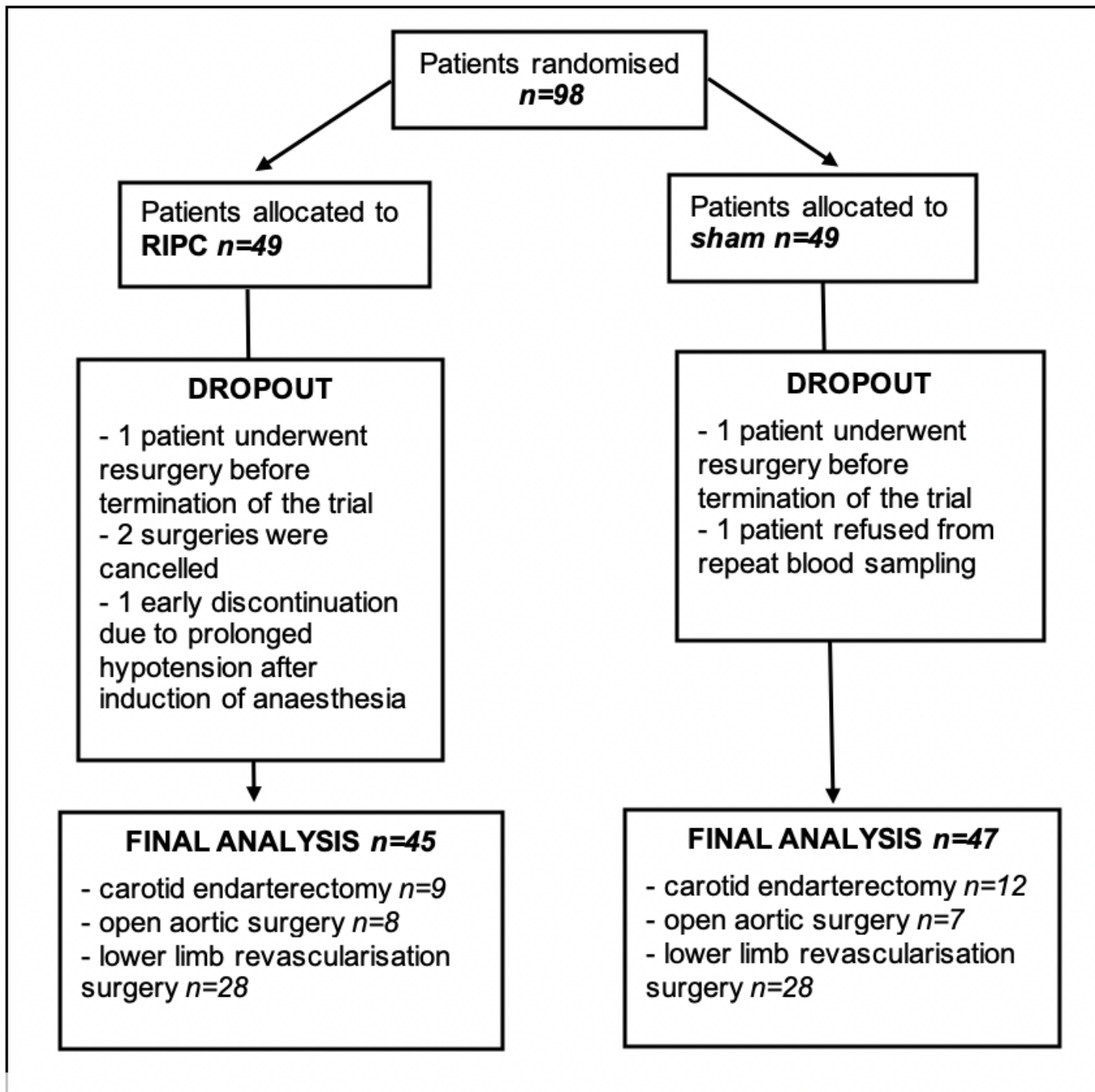
Figure 1

Patients' flow chart

Supplementary Files

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- Supplementarytable.docx