**Table 1:** Characteristics of patients by presence or absence of heart failure and classified by right atrial pressure

measured using near-infrared spectroscopy

**Variable Missing Controls HF *P*-value HF and HF and HF and *P*-value**

**values (*n* = 49) (*n* = 243) RAP ≤5 RAP 6 – 9 RAP ≥ 10**

**(*n* = 80) (*n* = 88) (*n* = 75)**

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RAP by NIRS, mmHg 0 4 (3 – 8) 7 (4 – 11) *<*0.001 4 (2 – 4) 7 (6 – 8) 12 (11 – 14) NA

RAP by NIRS range, mmHg 0 1 – 13 1 –20 NA NA NA NA NA

**Demographics**

Age, years 0 72 (8) 71 (10) 0.53 69 (10) 72 (10) 72 (10) 0.033

Men, no. (%) 0 24 (49) 155 (64) 0.052 54 (68) 55 (63) 46 (61) 0.69

NYHA class I 0 41 (84) 70 (29) *<*0.001 30 (37) 24 (28) 16 (21) 0.016

NYHA class II 7 (14) 112 (46) 40 (50) 39 (44) 33 (44)

NYHA class III 1 (2) 61 (25) 10 (13) 25 (28) 26 (35)

IHD, no. (%) 0 8 (16) 142 (58) *<*0.001 43 (54) 52 (59) 47 (63) 0.52

DM, no. (%) 0 41 (84) 100 (41) *<*0.001 29 (36) 42 (48) 29 (39) 0.27

Hypertension, no. (%) 0 34 (69) 108 (44) 0.001 30 (37) 43 (49) 35 (47) 0.30

Atrial fibrillation, no. (%) 0 0 (0) 69 (28) *<*0.001 12 (15) 25 (28) 32 (43) 0.001

COPD, no. (%) 0 3 (6) 13 (5) 0.83 1 (1) 7 (8) 5 (7) 0.12

SBP, mmHg 0 144 (18) 127 (23) *<*0.001 125 (21) 129 (26) 127 (22) 0.55

Heart rate, b.p.m. 0 76 (15) 68 (14) 0.001 68 (12) 69 (15) 67 (14) 0.74

BMI, kg/m2 0 31 (6) 30 (6) 0.23 31 (6) 30 (7) 28 (5) 0.10

BSA, m2 0 1.9 (0.3) 1.9 (0.2) 0.32 2.0 (0.2) 1.9 (0.2) 1.9 (0.2) 0.25

Congestion ≥ 3, no. (%) 0 2 (4) 25 (10) 0.17 1 (1) 5 (6) 19 (25) *<*0.001

JVP not visible (=0), no. (%) 0 48 (96) 193 (80) 0.008 79 (99) 70 (80) 44 (59) *<*0.001

JVP raised 1 –4 cm (=1), no. (%) 0 1 (2) 42 (17) 1 (1) 18 (2) 23 (31)

JVP raised to earlobe (=2), no. 0 0 (0) 8 (3) 0 (0) 0 (0) 8 (10)

(%)

**Bloods**

Creatinine, μmol/L 0 76 (66 – 88) 97 (81 – 130) *<*0.001 96 (77 – 117) 95 (76 – 132) 102 (85 – 156) 0.10

Urea, mmol/L 0 5.9 (5.2 – 7.0) 7.7 (5.8 – 11.0) *<*0.001 7.4 (5.5 – 9.1) 7.4 (5.5 – 11) 8.7 (6.4 – 13) 0.03

eGFR, mL/min/1.73 m2 0 91 (25) 66 (27) *<*0.001 69 (28) 69 (28) 60 (24) 0.04

Haemoglobin, g/dL 1 13.6 (1.5) 13.3 (1.6) 0.25 13.7 (1.3) 13.4 (1.5) 12.7 (1.7) *<*0.001

Albumin, g/L 0 39 (3) 38 (3) 0.06 38 (3) 39 (3) 38 (4) 0.32

Bilirubin, μmol/L 0 14.7 (4.8) 17.2 (6.6) 0.011 17.0 (7.6) 16.9 (5.6) 17.7 (6.3) 0.73

NT-proBNP, ng/L 1 72 (45 – 104) 788 (280 – 1841) *<*0.001 406 (191 – 892) 903 (276 – 1922) 1549 (703 – 3058) *<*0.001

NT-proBNP, ng/L (patients in 0 72 (45 – 104) 441 (223 – 1284) *<*0.001 347 (183 – 836) 421 (216– 1452) 957 (311 – 2897) 0.001

sinus rhythm only)

**Treatment**

Beta-blocker, no. (%) 0 13 (27) 195 (80) *<*0.001 64 (80) 74 (84) 57 (76) 0.43

ACE-I/ARB, no (%) 0 21 (43) 186 (77) *<*0.001 60 (75) 69 (78) 57 (76) 0.86

Aldosterone antagonist, no. (%) 0 4 (8) 115 (47) *<*0.001 37 (46) 43 (49) 35 (47) 0.93

Loop diuretic, no. (%) 0 5 (10) 152 (63) *<*0.001 46 (57) 55 (63) 51 (68) 0.40

Loop *>*40 mg furosemide, no. (%) 0 0 (0) 50 (21) *<*0.001 14 (18) 15 (17) 21 (28) 0.16

**Ultrasound**

LVEDD, cm 0 4.6 (0.6) 5.5 (0.9) *<*0.001 5.5 (0.8) 5.4 (0.9) 5.7(1.0) 0.057

LVEDV, mL 0 92 (29) 139 (64) *<*0.001 134 (49) 130 (59) 154 (80) 0.04

LVEF, % 0 60 (5) 45 (13) *<*0.001 46 (12) 46 (12) 45 (14) 0.77

LVEF ≤40%, no. (%) 0 0 (0) 86 (35) *<*0.001 28 (35) 31 (35) 27 (36) 0.99

LAVI, mL/m2 1 26 (9) 39 (17) *<*0.001 33 (13) 38 (15) 46 (20) *<*0.001

Mitral E/E′ 7 8.9 (2.8) 12.2 (6.3) 0.001 11.4 (6.7) 11.7 (4.5) 13.7 (7.4) 0.058

TAPSE, cm 2 2.2 (0.3) 1.8 (0.4) *<*0.001 1.9 (0.3) 1.9 (0.4) 1.7 (0.5) 0.001

TR gradient, mmHg 37 22 (5) 27 (11) *<*0.001 24 (9) 26 (8) 34 (13) *<*0.001

IVC, cm 12 1.5 (0.3) 1.9 (0.4) *<*0.001 1.7 (0.3) 1.9 (0.4) 2.1 (0.5) *<*0.001

IVC ≤16 mm, no. (%) 12 28 (61) 68 (29) *<*0.001 37 (50) 22 (26) 9 (12) *<*0.001

IVC 17 – 20 mm, no. (%) 15 (33) 89 (38) 24 (33) 37 (43) 28 (38)

IVC *>*20 mm, no. (%) 3 (6) 77 (33) 13 (17) 27 (31) 37 (50)

Mitral regurgitation *<*0.001 0.014

Mild 0 11 (22) 105 (43) 32 (40) 39 (44) 34 (45)

Moderate/severe 0 (0) 31 (13) 4 (5) 11 (12) 16 (21)

Tricuspid regurgitation *<*0.001 *<*0.001

Mild 0 6 (12) 82 (34) 22 (27) 28 (32) 32 (43)

Moderate/severe 0 (0) 32 (13) 2 (3) 11 (13) 19 (25)

JVD rest, cm 7 0.15 (0.04) 0.25 (0.24) *<*0.001 0.18 (0.08) 0.19 (0.1) 0.40 (0.37) *<*0.001

JVD deep inspiration, cm 7 0.09 (0.03) 0.18 (0.23) *<*0.001 0.11 (0.08) 0.13 (0.08) 0.32 (0.40) *<*0.001

JVD maximal, cm 7 1.02 (0.17) 1.07 (0.22) 0.09 1.05 (0.18) 1.04 (0.19) 1.12 (0.27) 0.057

JVD ratio (max/baseline) 7 6.9 (1.3) 5.8 (2.3) *<*0.001 6.4 (2.0) 6.1 (2.0) 4.7 (2.6) *<*0.001

JVD ratio *>*4, no. (%) 7 46 (98) 189 (79) 0.002 72 (90) 73 (86) 44 (60) *<*0.001

JVD ratio ≤4, no. (%) 1 (2) 49 (21) 8 (10) 12 (14) 29 (40)

ACE-I, ACE inhibitors; ARB, angiotensin receptor blockers; BMI, body mass index; BSA, body surface area; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; eGFR, estimated glomerular filtration rate; IHD, ischaemic heart disease; IVC, inferior vena cava; JVD, jugular vein diameter; JVP, jugular venous pressure; LAVI, left atrial volume index; LVEDD, left ventricular end-diastolic diameter; LVEDV, left ventricular end-diastolic volume; LVEF, left ventricular ejection fraction; NA, not applicable; NIRS, near-infrared spectroscopy; NT-proBNP, N-terminal B-type natriuretic peptide; RAP, right atrial pressure; SBP, systolic blood pressure; TAPSE, tricuspid annular plane systolic excursion; TR gradient, trans-tricuspid systolic gradient.

**Table 2:** Variables associated with right atrial pressure measured by near-infrared spectroscopy only in patients with heart failure

**Variable Univariable analysis Multivariable analysis**

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**Correlation coefficient *P*-value Unstandardized coefficients (95% CI) *t*-stat (*P*-value)**

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**Demographics**

Age, years 0.166 0.010

SBP, mmHg 0.000 0.999

Heart rate, b.p.m. −0.007 0.916

BMI, kg/m2 −0.076 0.239

BSA, m2 −0.091 0.157

**Bloods**

log(creatinine) 0.150 0.019

log(urea) 0.180 0.005

eGFR, mL/min/1.73 m2 −0.167 0.009

Haemoglobin, g/dL −0.284 *<*0.001 −0.043 (−0.073;−0.013) −2.824 (0.005)

Albumin, g/L 0.011 0.859

Bilirubin, μmol/L 0.035 0.584

log(NT-proBNP) 0.370 *<*0.001 1.222 (0.085;2.358) 2.119 (0.035)

**Ultrasound**

LVEDV, mL 0.073 0.258

LVEDD, cm 0.101 0.115

LVEF, % −0.040 0.536

Mitral E/E′ 0.091 0.161

LAVI, mL/m2 0.291 *<*0.001

TAPSE, cm −0.178 0.006

TR gradient, mmHg 0.354 *<*0.001

IVC, cm 0.461 *<*0.001 3.313 (2.207;4.419) 5.903 (*<*0.001)

JVD rest, cm 0.348 *<*0.001

JVD deep inspiration, cm 0.354 *<*0.001

JVD maximal, cm 0.108 0.097

JVD ratio (max/baseline) −0.306 *<*0.001

Results were obtained from univariable and multivariable linear regression models. The first column on the left (univariable analysis) represents the correlation between RAP measured by NIRS and the variables studied. The column for the multivariable analysis (left) shows the coefficients for slope of the linear relation between all the variables independently associated with RAP measured by NIRS [R2 = 0.33, adjusted R2 = 0.31; variables entered in multivariable analysis: age, log(NT-proBNP), log(creatinine), TAPSE, IVC, haemoglobin, LAVI].

BMI, body mass index; BSA, body surface area; eGFR, estimated glomerular filtration rate; IVC, inferior vena cava; JVD, jugular vein diameter; LAVI, left atrial volume index; LVEDD, left ventricular end-diastolic diameter; LVEDV, left ventricular end-diastolic volume; LVEF, left ventricular ejection fraction; NT-proBNP, N-terminal B-type natriuretic peptide; SBP, systolic blood pressure; TAPSE, tricuspid annular plane systolic excursion; TR gradient, trans-tricuspid systolic gradient.

**Table 3:** Univariable Cox regression model for the composite endpoint of death from all causes or heart failure hospitalization in patients with heart failure (n = 243 patients with heart failure who had 49 events)

**Variables Univariable analysis**

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**HR (95% CI) 𝝌 2 *P*-value**

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RAP by NIRS, mmHg 1.10 (1.04 – 1.18) 10.06 0.002

**Demographics**

Age, years 1.03 (0.99 – 1.06) 3.18 0.08

Sex (men vs. women) 1.47 (0.79 – 2.73) 1.46 0.23

NYHA class III vs. I/II 2.51 (1.43 – 4.43) 10.19 0.001

IHD (yes vs. no) 2.45 (1.27 – 4.70) 7.27 0.007

DM (yes vs. no) 1.18 (0.67 – 2.08) 0.35 0.55

Hypertension (yes vs. no) 1.21 (0.69 – 2.12) 0.46 0.49

Atrial fibrillation (yes vs. no) 1.59 (0.79 – 3.11) 1.72 0.19

COPD (yes vs. no) 1.58 (0.57 – 4.38) 0.76 0.38

SBP, mmHg 0.99 (0.98 – 1.00) 0.74 0.39

Heart rate, b.p.m. 1.01 (0.99 – 1.03) 0.94 0.33

BMI, kg/m2 1.01 (0.97 – 1.06) 0.33 0.57

BSA, m2 1.75 (0.52 – 5.87) 0.83 0.36

Congestion ≥3 signs 3.56 (1.86 – 6.84) 14.60 *<*0.001

Clinical JVP (2/1 vs. 0) 2.20 (1.21 –4.01) 6.71 0.01

**Bloods**

Creatinine, μmol/L 1.01 (1.00 – 1.01) 3.66 0.056

Urea, mmol/L 1.06 (1.01 – 1.10) 5.17 0.02

eGFR, mL/min/1.73 m2 0.99 (0.98 – 1.00) 3.41 0.065

Haemoglobin, g/dL 0.98 (0.96 – 1.00) 6.22 0.013

Albumin, g/L 0.88 (0.81 – 0.94) 11.50 0.001

Bilirubin, μmol/L 1.02 (0.98 – 1.06) 1.29 0.26

log(NT-proBNP) 4.01 (2.30 – 6.99) 23.97 *<*0.001

**Ultrasound**

LVEDV, mL 1.01 (1.00 – 1.01) 11.77 0.001

LVEDD, cm 1.77 (1.32 – 2.37) 14.72 *<*0.001

LVEF, % 0.97 (0.95 – 0.99) 8.70 0.003

E/E′ 1.04 (1.01 – 1.08) 7.99 0.005

LAVI, mL/m2 1.02 (1.01 – 1.04) 8.13 0.004

TAPSE, cm 0.42 (0.21 – 0.87) 5.40 0.02

TR gradient, mmHg 1.04 (1.02 – 1.06) 16.28 *<*0.001

IVC, cm 3.94 (2.18–7.11) 20.55 *<*0.001

MR, moderate vs. none/mild 2.92 (1.55 – 5.51) 10.94 0.001

TR, moderate vs. none/mild 2.66 (1.38 – 5.12) 8.60 0.003

JVD rest, cm 4.56 (2.26 – 9.21) 17.94 *<*0.001

JVD deep inspiration, cm 4.26 (2.11 – 8.60) 16.30 *<*0.001

JVD maximal, cm 2.77 (0.84 – 9.10) 2.81 0.09

JVD ratio (max/baseline) 0.79 (0.70 – 0.90) 12.66 *<*0.001

For continuous variables, the values are the hazard ratios associated with a unitary increase in that variable.

BMI, body mass index; BSA, body surface area; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; eGFR, estimated glomerular filtration rate; IHD, ischaemic heart disease; IVC, inferior vena cava; JVD, jugular vein diameter; JVP, jugular venous pressure; LAVI, left atrial volume index; LVEDD, left ventricular end-diastolic diameter; LVEDV, left ventricular end-diastolic volume; LVEF, left ventricular ejection fraction; NIRS, near-infrared spectroscopy; NT-proBNP, N-terminal B-type natriuretic peptide; RAP, right atrial pressure; SBP, systolic blood pressure; TAPSE, tricuspid annular plane systolic excursion; TR gradient, trans-tricuspid systolic gradient.

**Table 4:** Multivariable Cox regression model for the composite endpoint of death from all causes or heart failure hospitalization in patients with heart failure (n = 243 patients with heart failure who had 49 events)

**Model A-1 Model A-2**

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**HR (95% CI) 𝝌 2 *P*-value HR (95% CI) 𝝌 2 *P*-value**

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Age, years 1.01 (0.98 – 1.05) 0.65 0.42 1.02 (0.99 – 1.06) 2.15 0.15

NYHA III vs. II/I 1.43 (0.76 – 2.71) 1.21 0.27 1.56 (0.83 – 2.92) 1.94 0.16

RAP by NIRS, mmHg 1.04 (0.97 – 1.11) 1.17 0.28 1.08 (1.01 – 1.15) 5.01 0.03

Creatinine, μmol/L 1.01 (1.00 – 1.01) 0.01 0.97 1.01 (1.00 – 1.01) 0.18 0.67

LVEF, % 0.99 (0.96 – 1.01) 1.20 0.27 0.97 (0.95 – 0.99) 5.37 0.02

log(NT-proBNP) 2.40 (1.13–5.10) 5.17 0.02 – – –

**Model B-1 Model B-2**

Age, years 1.00 (0.97 – 1.03) 0.02 0.88 1.01 (0.97 – 1.04) 0.10 0.76

Urea, mmol/L 1.01 (0.95 – 1.07) 0.09 0.76 1.04 (0.99 – 1.09) 1.85 0.17

Haemoglobin, g/dL 0.99 (0.98 – 1.01) 0.38 0.54 0.99 (0.98 – 1.01) 0.33 0.56

Albumin, g/L 0.90 (0.84 – 0.99) 5.31 0.02 0.90 (0.83 – 0.97) 7.34 0.007

log(NT-proBNP) 2.89 (1.47 – 5.65) 9.54 0.002 – – –

RAP by NIRS, mmHg 1.03 (0.96 – 1.11) 0.71 0.40 1.08 (1.01 – 1.16) 5.63 0.02

**Model C-1 Model C-2**

Age, years 1.03 (0.00 – 1.06) 2.36 0.12 1.01 (0.98 – 1.04) 0.52 0.47

LVEF, % 0.98 (0.95 – 1.00) 3.28 0.07 0.98 (0.95 – 1.00) 3.42 0.06

E/E′ 1.02 (0.98 – 1.07) 0.79 0.37 1.02 (0.98 – 1.06) 1.07 0.30

LAVI, mL/m2 1.01 (0.99 – 1.03) 0.98 0.32 1.01 (0.99 – 1.02) 0.57 0.45

TAPSE, cm 0.86 (0.40 – 1.86) 0.14 0.71 – – –

IVC, cm – – – 2.73 (1.29 – 5.74) 7.01 0.008

RAP by NIRS, mmHg 1.08 (1.01 – 1.15) 4.40 0.036 1.03 (0.95 – 1.11) 0.38 0.54

Different models were tested to explore how the inclusion or exclusion of known predictors of outcome affects the impact of RAP by NIRS. This is relevant to the clinical setting, when information is often incomplete. It also shows whether variables that are associated with RAP also provide similar prognostic information.

IVC, inferior vena cava; LAVI, left atrial volume index; LVEF, left ventricular ejection fraction; NIRS, near-infrared spectroscopy; NT-proBNP, N-terminal B-type natriuretic peptide; RAP, right atrial pressure; TAPSE, tricuspid annular plane systolic excursion.