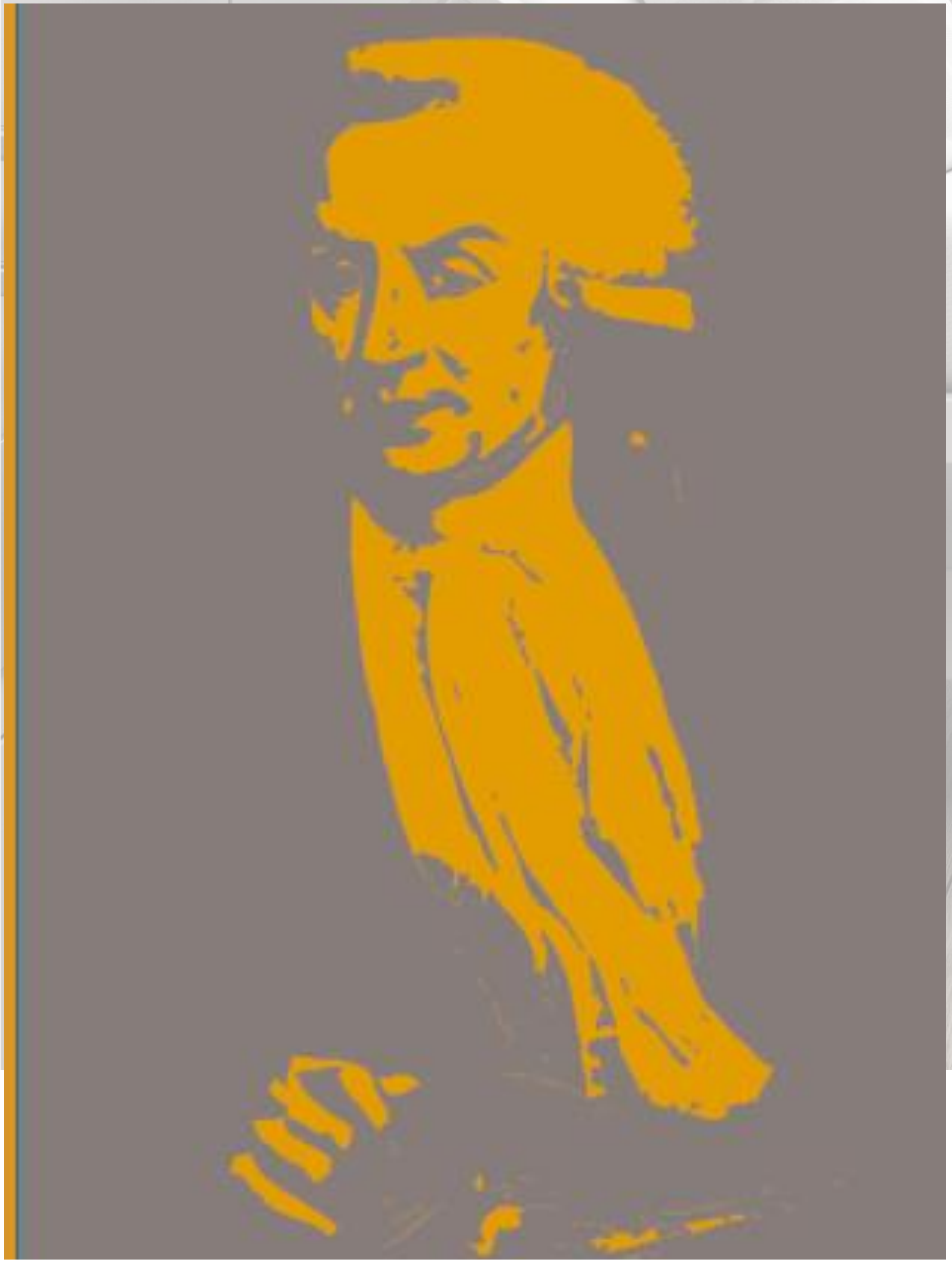
به نام خدا

Patient Management through BWA :
The Medical Value of Accurate Body Composition Analysis



Luigi Aloisius Galvani 1737-1798

Mohammad Taghi Najafi M.D.
Associate Professor of Nephrology TUMS

Who Dedicates his life to Diagnose and Treat

High Blood Pressure

Oct 2024

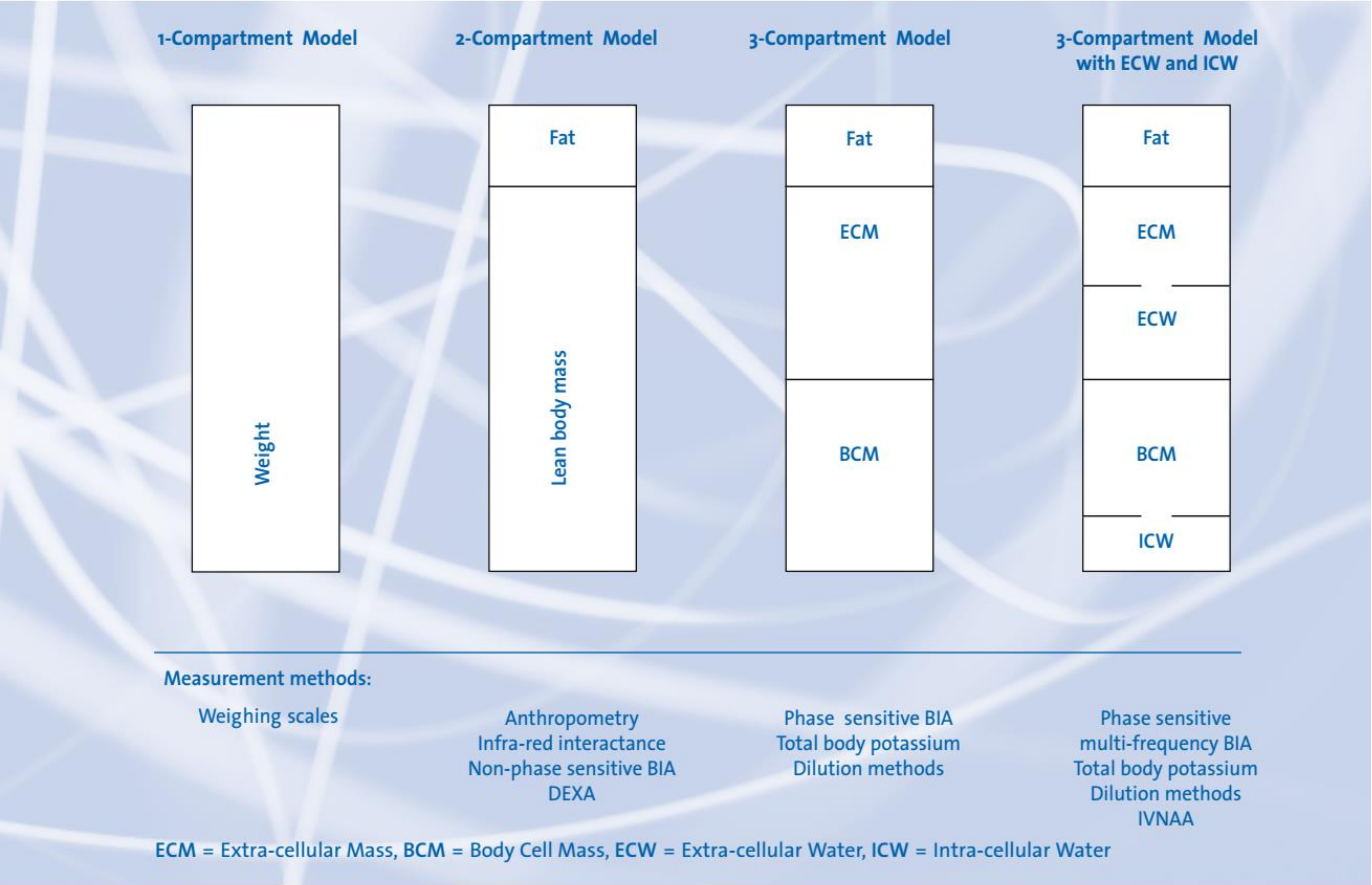
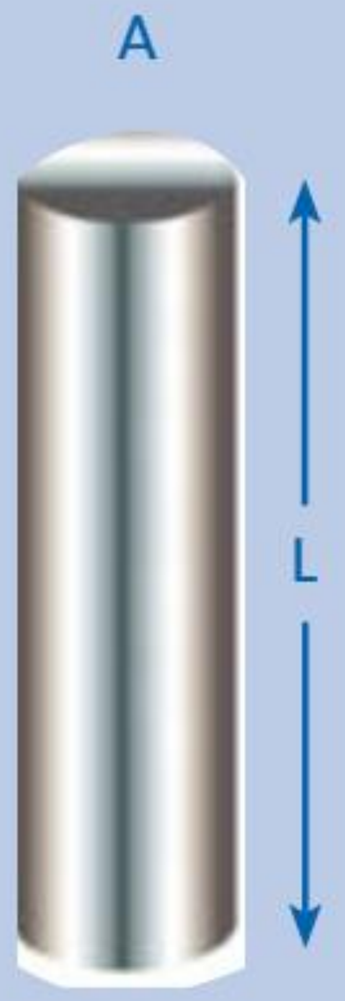


Fig. B.1 Schematic representation of the compartment models

$Z = L / A$

whereby

Z = impedance
L = length of the conductor (cm)
A = cross-sectional area (cm2)

Fig. C.1 The resistance of a cylinder

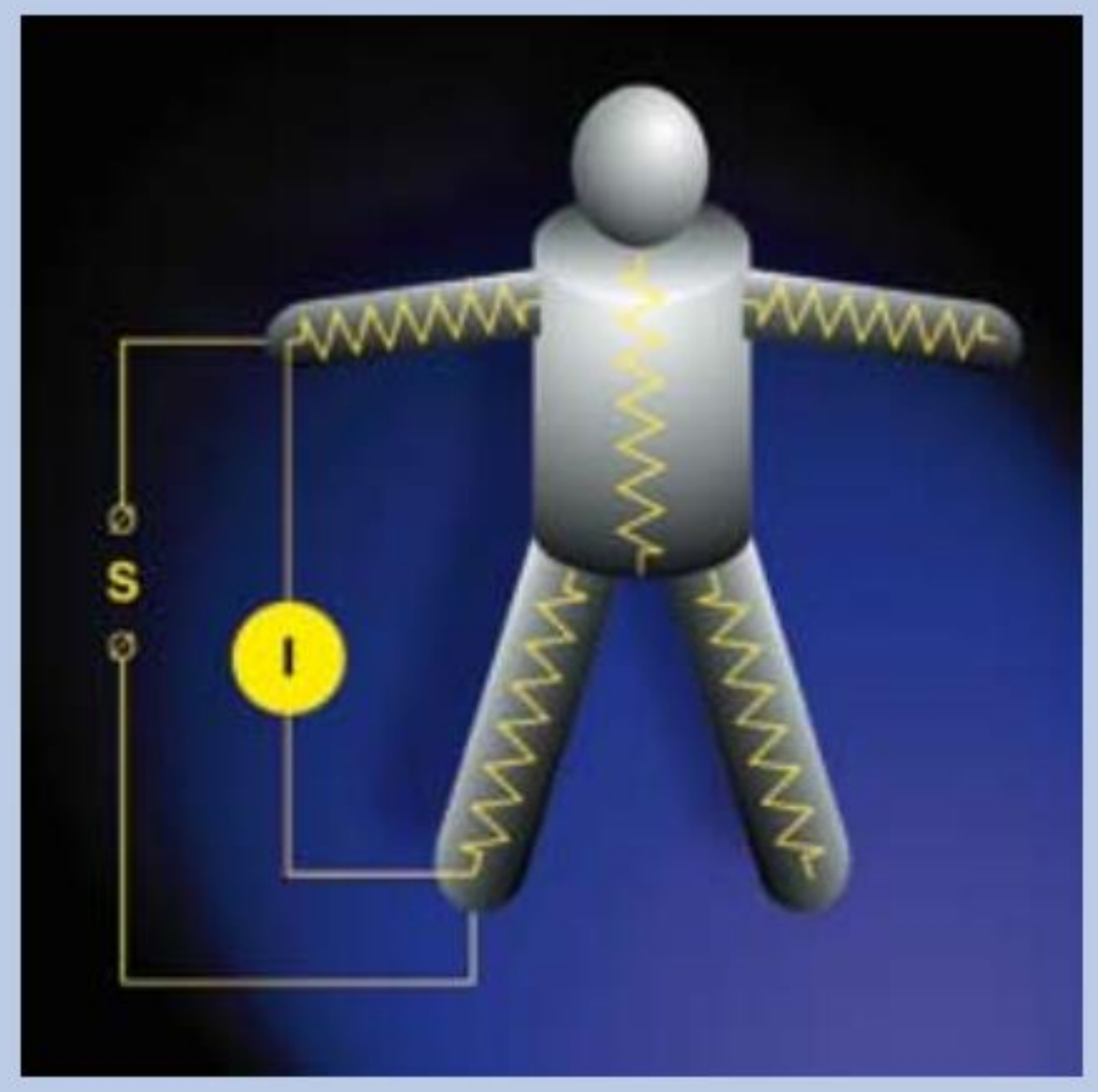


Fig. C.2 The electrical circuits of the human body

$$\text{Water content} = \frac{\text{body length}^2}{\text{impedance}}$$

or

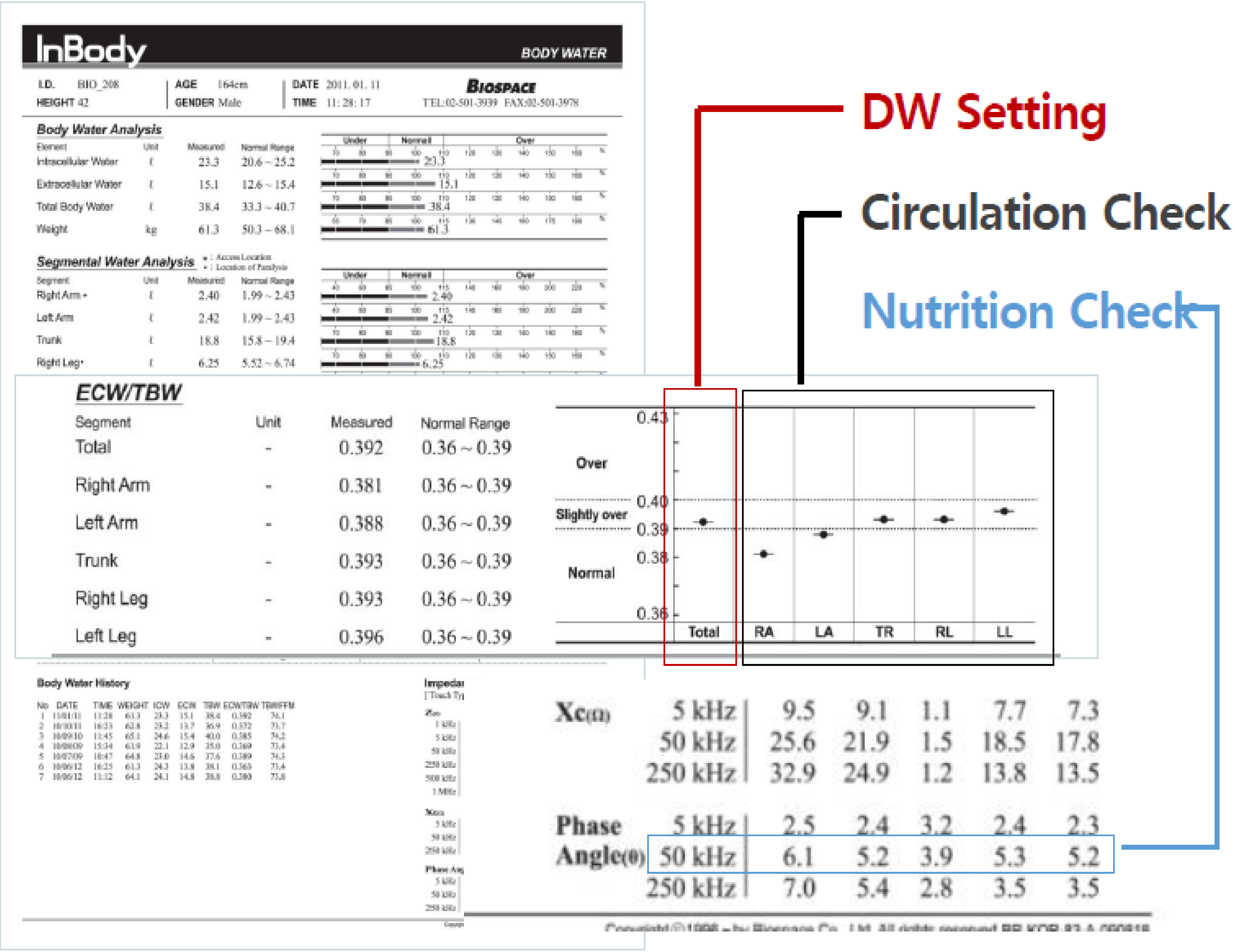
$$\text{Total Body Water} = \frac{\text{Height}^2}{\text{impedance}},$$

abbreviated

$$\text{TBW} = \frac{\text{Ht}^2}{Z}$$

This formula is the base for the calculation of the Total Body Water.

S10 Utilization on HD patient



Body Water Analysis

Element	Unit	Measured	Normal Range
Intracellular Water	ℓ	23.3	20.6 ~ 25.2
Extracellular Water	ℓ	15.1	12.6 ~ 15.4
Total Body Water	ℓ	38.4	33.3 ~ 40.7
Weight	kg	61.3	50.3 ~ 68.1

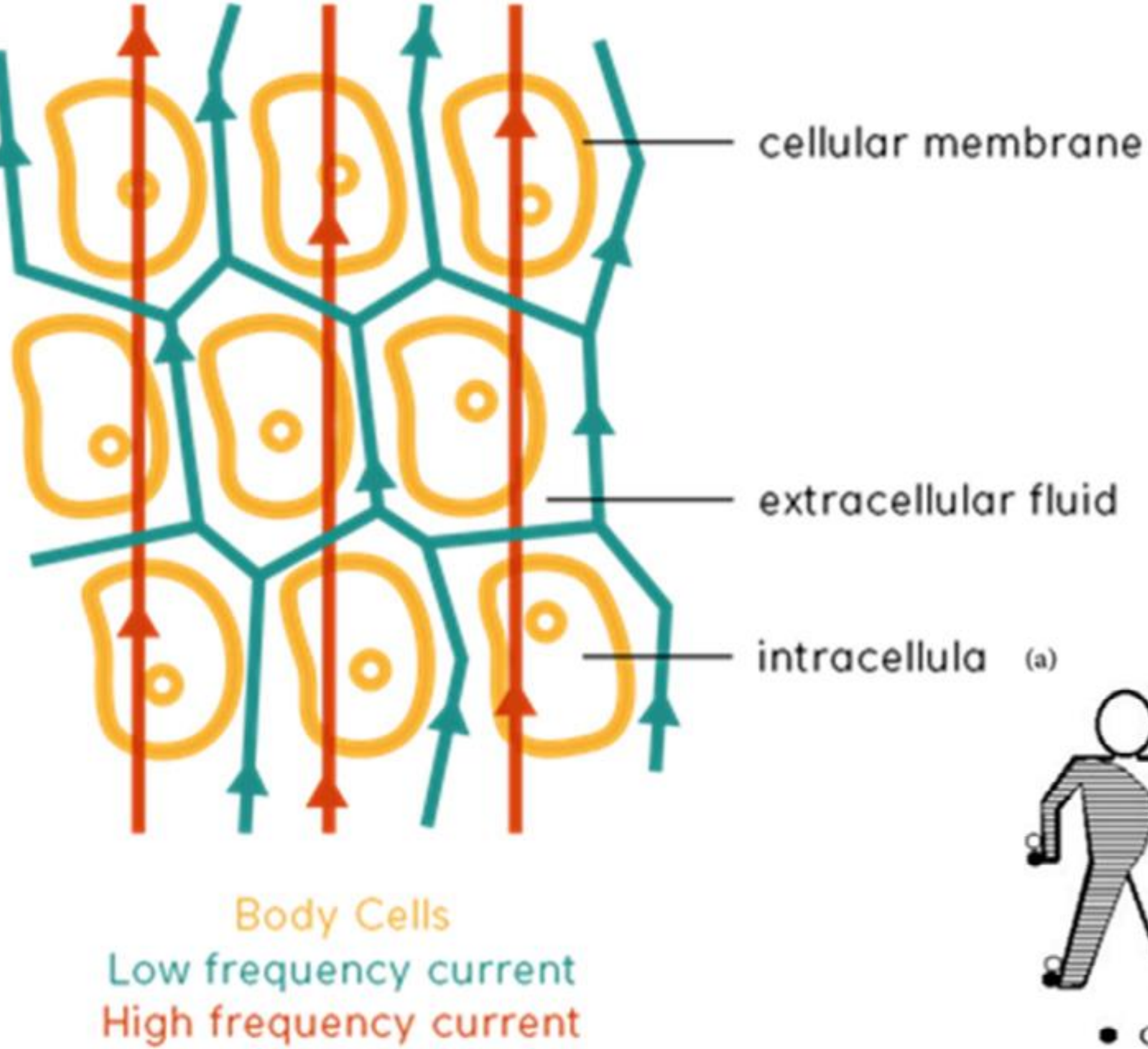
Segmental Water Analysis

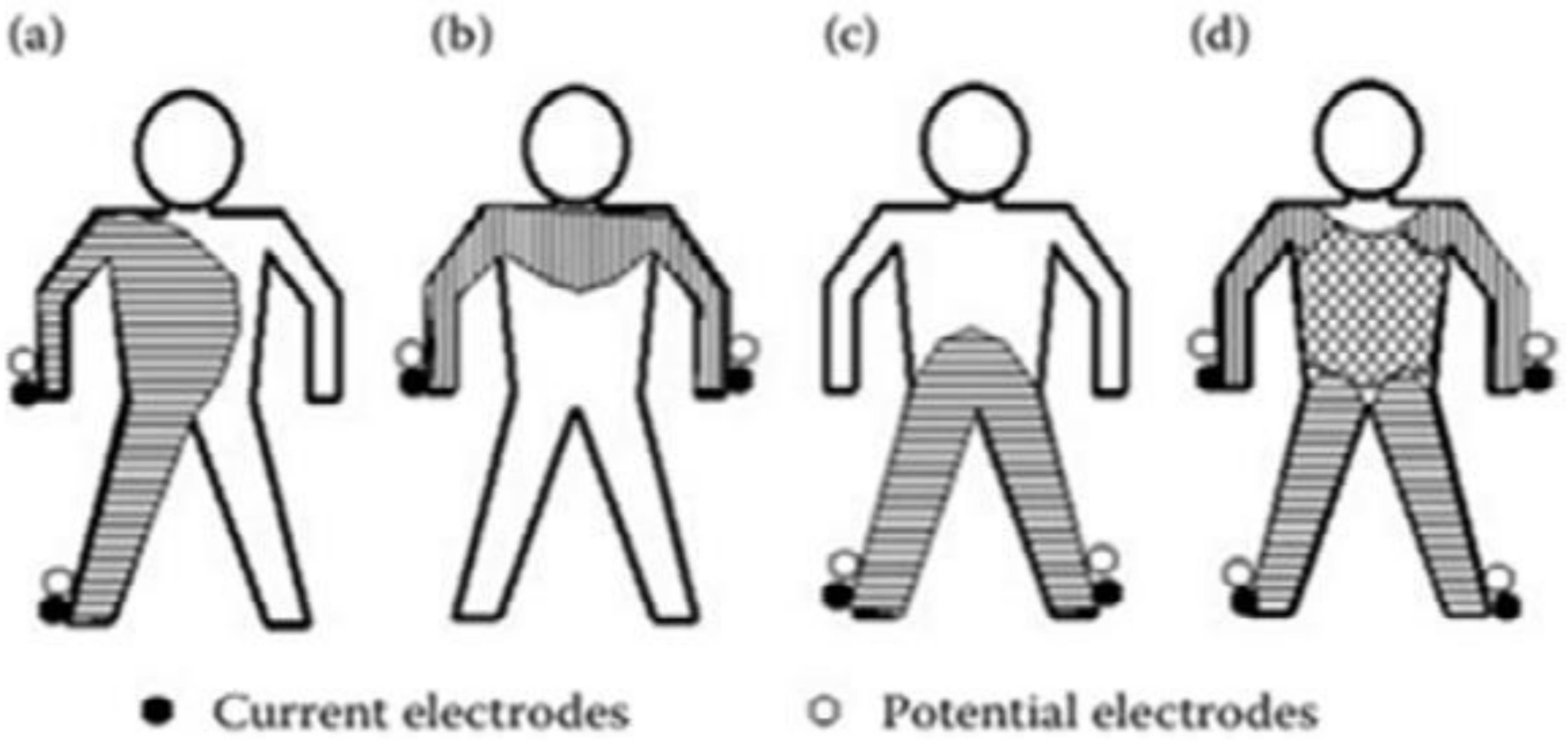
Segment	Unit	Measured	Normal Range
Right Arm •	ℓ	2.40	1.99 ~ 2.43
Left Arm	ℓ	2.42	1.99 ~ 2.43
Trunk	ℓ	18.8	15.8 ~ 19.4
Right Leg•	ℓ	6.25	5.52 ~ 6.74

ECW/TBW

Segment	Unit	Measured	Normal Range
Total	-	0.392	0.36 ~ 0.39
Right Arm	-	0.381	0.36 ~ 0.39
Left Arm	-	0.388	0.36 ~ 0.39
Trunk	-	0.393	0.36 ~ 0.39
Right Leg	-	0.393	0.36 ~ 0.39
Left Leg	-	0.396	0.36 ~ 0.39

		RA	LA	TR	RL	LL
Xc(Ω)	5 kHz	9.5	9.1	1.1	7.7	7.3
	50 kHz	25.6	21.9	1.5	18.5	17.8
	250 kHz	32.9	24.9	1.2	13.8	13.5
Phase Angle(θ)	5 kHz	2.5	2.4	3.2	2.4	2.3
	50 kHz	6.1	5.2	3.9	5.3	5.2
	250 kHz	7.0	5.4	2.8	3.5	3.5


cellular membrane
extracellular fluid
intracellula
Body Cells
Low frequency current
High frequency current


(a)
(b)
(c)
(d)
Current electrodes
Potential electrodes

CASE 1

InBody [InBodyS10]

ID	Height	Age	Gender	Test Date / Time
191022-1	170cm	54	Female	19.10.2022. 12:26

Body Composition Analysis

	Values	Total Body Water	Soft Lean Mass	Fat Free Mass	Weight
Total Body Water (L)	37,2 (31,7~38,7)	37,2	47,0 (40,7~49,7)	50,0 (43,1~52,6)	70,0 (52,8~71,4)
Protein (kg)	9,2 (8,5~10,3)				
Minerals (kg)	3,60 (2,92~3,58)	non-osseous			
Body Fat Mass (kg)	20,0 (12,4~19,9)				

Muscle-Fat Analysis

	Value
Weight (kg)	70,0
SMM Skeletal Muscle Mass (kg)	25,8
Body Fat Mass (kg)	20,0

Obesity Analysis

	Value
BMI Body Mass Index (kg/m²)	24,2
PBF Percent Body Fat (%)	28,6

Segmental Lean Analysis

Based on ideal weight / Based on current weight

	(kg)	(%)	ECW Ratio
Right Arm	3,14	132,9	0,408
Left Arm	3,14	133,2	0,415
Trunk	24,0	112,2	0,426
Right Leg	6,41	85,9	0,432
Left Leg	6,57	88,1	0,432

ECW Ratio Analysis

ECW Ratio 0,426

Body Composition History

	19.10.22. 12:26
Weight (kg)	70,0
SMM Skeletal Muscle Mass (kg)	25,8
PBF Percent Body Fat (%)	28,6
ECW Ratio	0,426

☑Recent ☐Total

Water Control

ECW Ratio 0.385	- 2,6 L /	67,4 kg
ECW Ratio 0.395	- 2,0 L /	68,0 kg
ECW Ratio 0.405	- 1,4 L /	68,6 kg

*The water control item shows the water level to be controlled based on the extracellular water ratio. This item shows the water level which varies as the extracellular water ratio is set differently according to the presence or absence of complications as described in a paper published in the 2008 Journal of the Japan Society for Dialysis Therapy (JSDT).

Segmental Body Water Analysis

Right Arm	2,47 L	(1,42~2,14)
Left Arm	2,48 L	(1,42~2,14)
Trunk	19,0 L	(14,6~17,8)
Right Leg	5,08 L	(5,07~6,19)
Left Leg	5,21 L	(5,07~6,19)

Research Parameters

Intracellular Water	21,3 L	(19,6~24,0)
Extracellular Water	15,9 L	(12,1~14,7)
Basal Metabolic Rate	1450 kcal	(1418~1651)
Waist Circumference	96,4 cm	
Visceral Fat Area	124,8 cm²	
Bone Mineral Content	3,01 kg	(2,41~2,95)
Body Cell Mass	30,6 kg	(28,1~34,3)
Arm Circumference	29,1 cm	
TBW/FFM	74,3 %	
SMI	6,7 kg/m²	

Reactance

Xc(Ω)	RA	LA	TR	RL	LL
5 kHz	5,4	4,9	0,2	5,2	3,3
50 kHz	8,8	6,5	0,3	7,5	7,2
250 kHz	7,0	4,5	0,0	5,6	6,2

Segmental Phase Angle

2,1°

ϕ(°)	RA	LA	TR	RL	LL
50 kHz	2,4	1,8	1,2	1,8	1,8

Impedance

Z(Ω)	RA	LA	TR	RL	LL
1 kHz	224,0	219,4	14,9	251,0	238,7
5 kHz	221,9	215,7	14,7	247,6	236,5
50 kHz	209,4	206,1	14,7	238,4	229,9
250 kHz	199,8	199,3	13,9	230,0	220,4
500 kHz	195,5	196,2	13,5	226,0	215,9
1000 kHz	190,3	192,7	13,4	220,5	210,7

[Adhesive Type , Lying Posture , During Dialyse]

InBody Body Water [InBodyS10]

ID	Height	Age	Gender	Test Date / Time
191022-1	170cm	54	Female	19.10.2022. 12:26

Body Water Composition

	Value
TBW Total Body Water (L)	37,2
ICW Intracellular Water (L)	21,3
ECW Extracellular Water (L)	15,9

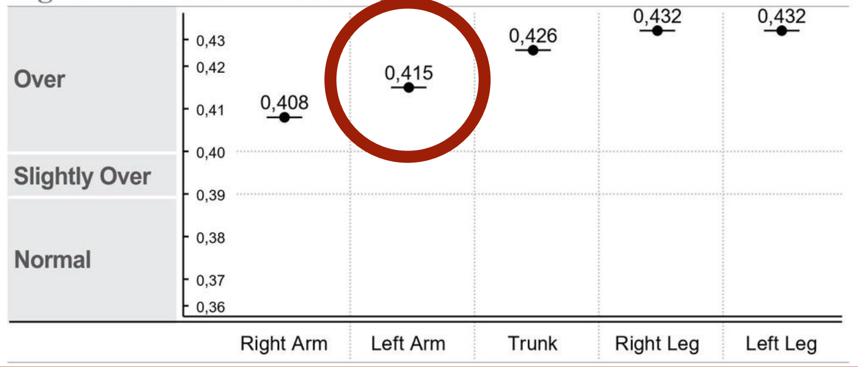
ECW Ratio Analysis

ECW Ratio 0,426

Segmental Body Water Analysis

	Value
Right Arm (L)	2,47
Left Arm (L)	2,48
Trunk (L)	19,0
Right Leg (L)	5,08
Left Leg (L)	5,21

Segmental ECW Ratio Analysis



Body Water Composition History

	19.10.22. 12:26
Weight (kg)	70,0
TBW Total Body Water (L)	37,2
ICW Intracellular Water (L)	21,3
ECW Extracellular Water (L)	15,9
ECW Ratio	0,426

☑Recent ☐Total

Body Water Composition

Total Body Water	37,2 L	(31,7~38,7)
Intracellular Water	21,3 L	(19,6~24,0)
Extracellular Water	15,9 L	(12,1~14,7)

Segmental Body Water Analysis

Right Arm	2,47 L	(1,42~2,14)
Left Arm	2,48 L	(1,42~2,14)
Trunk	19,0 L	(14,6~17,8)
Right Leg	5,08 L	(5,07~6,19)
Left Leg	5,21 L	(5,07~6,19)

Body Composition Analysis

Protein	9,2 kg	(8,5~10,3)
Minerals	3,60 kg	(2,92~3,58)
Body Fat Mass	20,0 kg	(12,4~19,9)
Fat Free Mass	50,0 kg	(43,1~52,6)
Bone Mineral Content	3,01 kg	(2,41~2,95)

Muscle-Fat Analysis

Weight	70,0 kg	(52,8~71,4)
Skeletal Muscle Mass	25,8 kg	(23,8~29,0)
Soft Lean Mass	47,0 kg	(40,7~49,7)
Body Fat Mass	20,0 kg	(12,4~19,9)

Obesity Analysis

BMI	24,2 kg/m²	(18,5~25,0)
PBF	28,6 %	(18,0~28,0)

Research Parameters

Basal Metabolic Rate	1450 kcal	(1418~1651)
Visceral Fat Area	124,8 cm²	
Body Cell Mass	30,6 kg	(28,1~34,3)
Arm Muscle Circumference	25,6 cm	
TBW/FFM	74,3 %	
SMI	6,7 kg/m²	

Reactance

Xc(Ω)	RA	LA	TR	RL	LL
5 kHz	5,4	4,9	0,2	5,2	3,3
50 kHz	8,8	6,5	0,3	7,5	7,2
250 kHz	7,0	4,5	0,0	5,6	6,2

Impedance

Z(Ω)	RA	LA	TR	RL	LL
1 kHz	224,0	219,4	14,9	251,0	238,7
5 kHz	221,9	215,7	14,7	247,6	236,5
50 kHz	209,4	206,1	14,7	238,4	229,9
250 kHz	199,8	199,3	13,9	230,0	220,4
500 kHz	195,5	196,2	13,5	226,0	215,9
1000 kHz	190,3	192,7	13,4	220,5	210,7

[Adhesive Type , Lying Posture , During Dialyse]

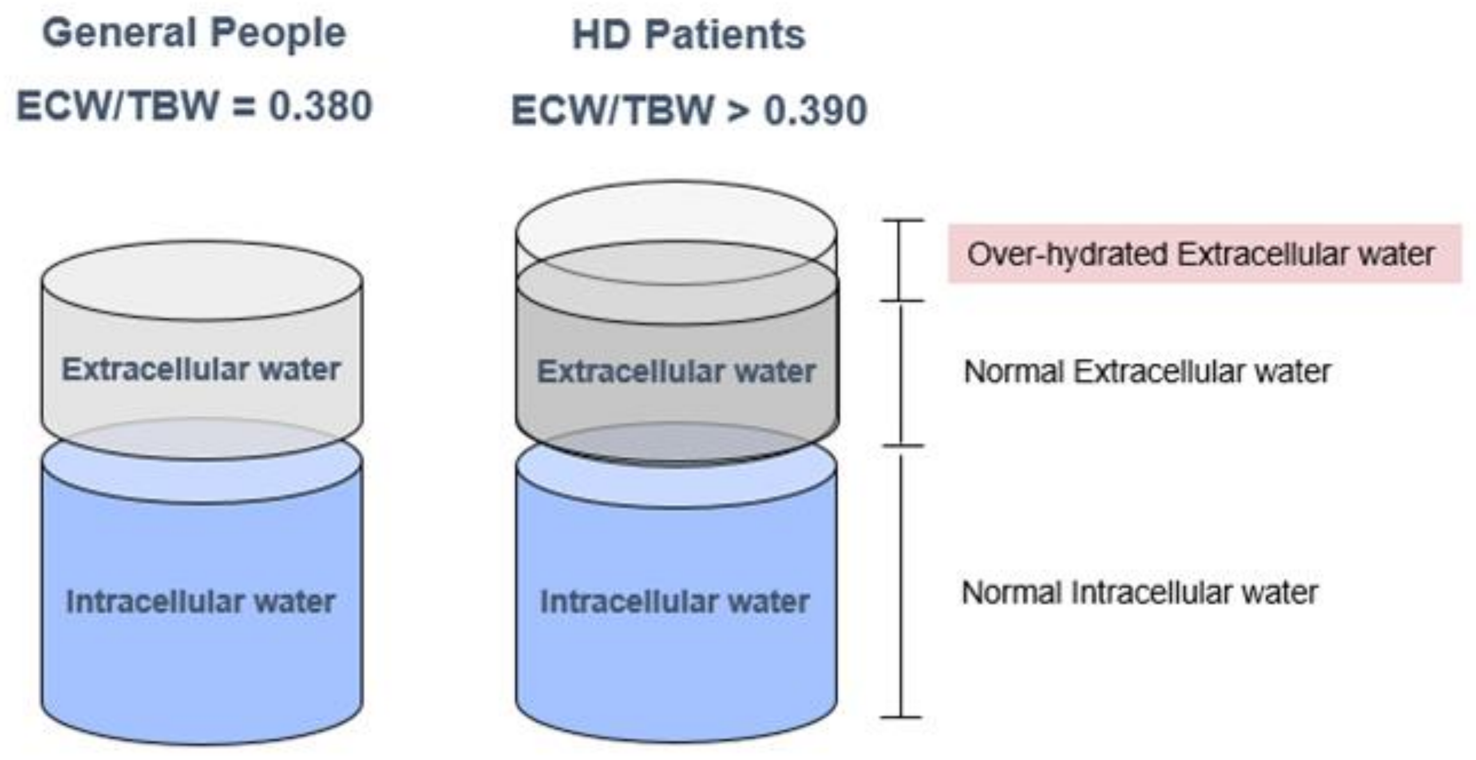
Female, 54 years old, 170cm, 70.0kg, Diabetic, Hypertensive Acute Renal failure, on CRRT

Dry Weight Check

Water Control

ECW Ratio 0.385	- 2,6 L	/	67,4 kg
ECW Ratio 0.395	- 2,0 L	/	68,0 kg
ECW Ratio 0.405	- 1,4 L	/	68,6 kg

*The water control item shows the water level to be controlled based on the extracellular water ratio. This item shows the water level which varies as the extracellular water ratio is set differently according to the presence or absence of complications as described in a paper published in the 2008 Journal of the Japan Society for Dialysis Therapy (JSDT).



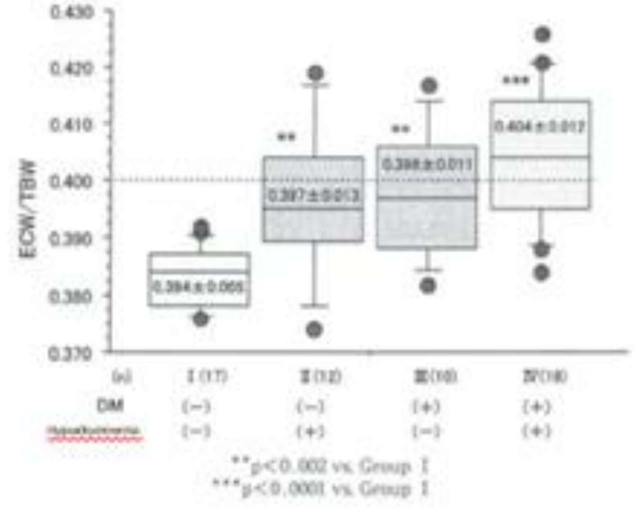
Based on normal ECW/TBW rate, extracellular water removal amounts can be calculated for a return to normality; that is, over-hydrated extracellular water. Dry weight can be calculated by subtracting over-hydrated extracellular water from current weight.


原　著

生体電気インピーダンス（BIA）法による DW 設定基準
―高精度体成分分析装置（InBody S20）による浮腫値（ECW/TBW）での検討―

The optimal ratio of extracellular water to total body water (ECW/TBW) determined by bioelectrical impedance analysis (BIA) for setting dry weight in hemodialysis patients

Nobuhiro Sasaki, Koushi Ueno, Takeshi Shiraishi, Akio Yoshimura, Munehiro Kuno, Shinichi Takeda, Takako Saitou, Yasuhiro Andou, Eiji Kusano
Kawashima Medical Clinic : Department of Nephrology, Jichi Medical University



Normal health people usually have 0.380 as a normal value of ECW/TBW, however, this study is indicating dialysis patients with other complications should not consider 0.380 as a normal value. For example, normal ECW/TBW value of dialysis patients with neither diabetes or hypoalbuminemia are considered to have 0.385, dialysis patients with either diabetes or hypoalbuminemia are considered to have 0.400. Lastly, patients with body diabetes and hypoalbuminemia are considered to have 0.405 as their normal range. Different adjustment of DW is required for the patients with complication disease.

Dialysis patients with diabetes or hypoalbuminemia have higher ECW/TBW value and this need to be considered when determining DW.

Dry Weight Check

Water Control

ECW Ratio 0.385	- 2,6 L	/ 67,4 kg
ECW Ratio 0.395	- 2,0 L	/ 68,0 kg
ECW Ratio 0.405	- 1,4 L	/ 68,6 kg

*The water control item shows the water level to be controlled based on the extracellular water ratio. This item shows the water level which varies as the extracellular water ratio is set differently according to the presence or absence of complications as described in a paper published in the 2008 Journal of the Japan Society for Dialysis Therapy (JSDT).

透析会誌 40(7)：581~588, 2007

原　著

高精度体成分分析装置(InBody S20)を用いた血液透析患者の体液量評価：生体電気インピーダンス(BIA)法はDWの指標になり得るか？

Assessment of body fluid component in hemodialyzed patients using a body composition analyzer (InBody S20) : Can the bioelectrical impedance method be a marker of dry weight ?

Nobuhiro Sasaki[*1,2], Koushi Ueno[*1], Takeshi Shiraishi[*1], Munehiro Kuno[*1], Eiko Nakazawa[*2], Eriko Ishii[*2], Yasuhiro Andou[*2], Eiji Kusano[*2]
Kawashima Medical Clinic[*1] : Department of Nephrology, Jichi Medical University[*2]

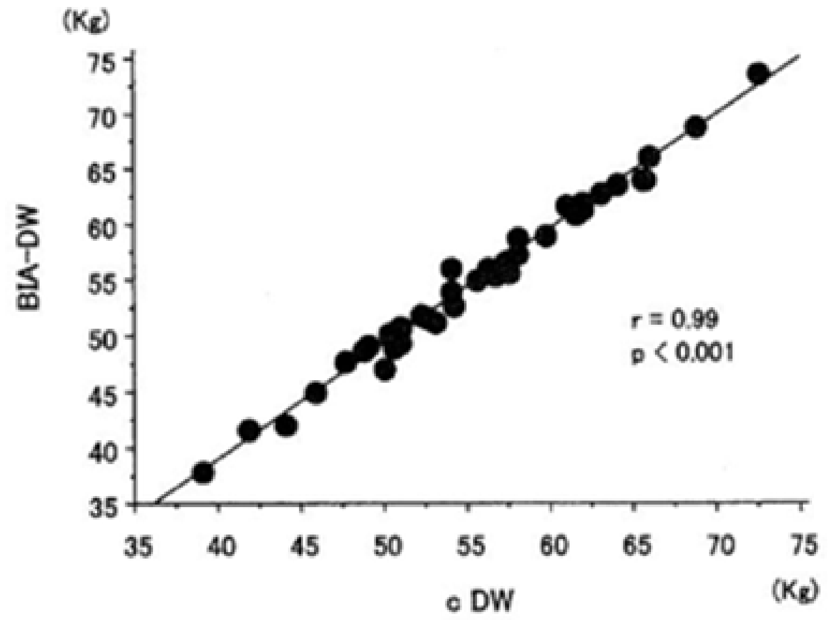


図 7　Relationship between the BIA-DW and the cDW

DW is determined by subtracting the water volume when the patient's ECW/TBW fall under 0.380 from the current weight.

This study have investigated whether the InBody was useful when assessing DW of dialysis patients by monitoring body water and the ratio of ECW/TBW. From the graph above, DW obtained from InBody were called BIA-DW and it was compared with the DW obtained by using CTR, hANP, IVC (cDW). And those two factors show significant correlation each other (r=0.99, p<0.001).

99% of correlation between the dry weight from InBody and from clinical methods(hANP, CTR, IVC)

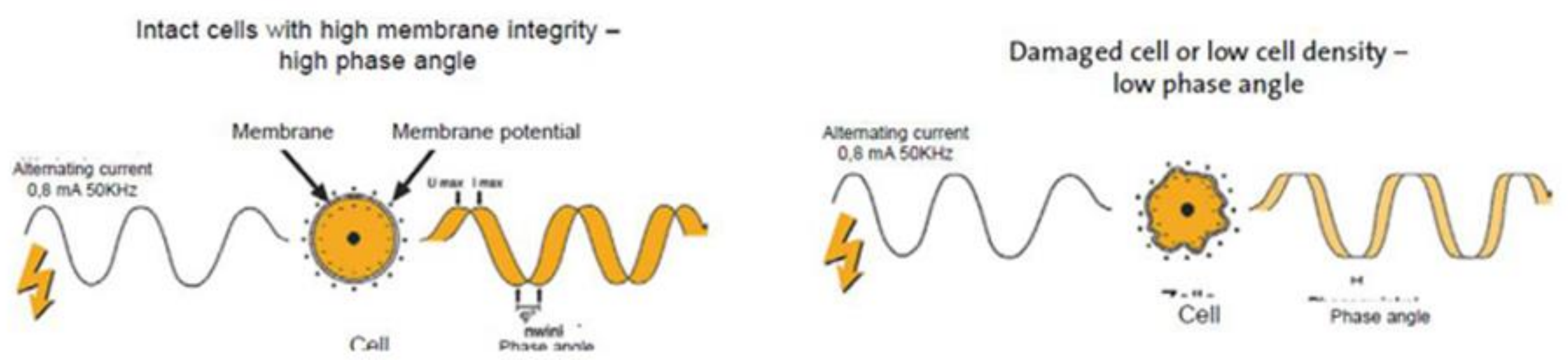
Severity Check

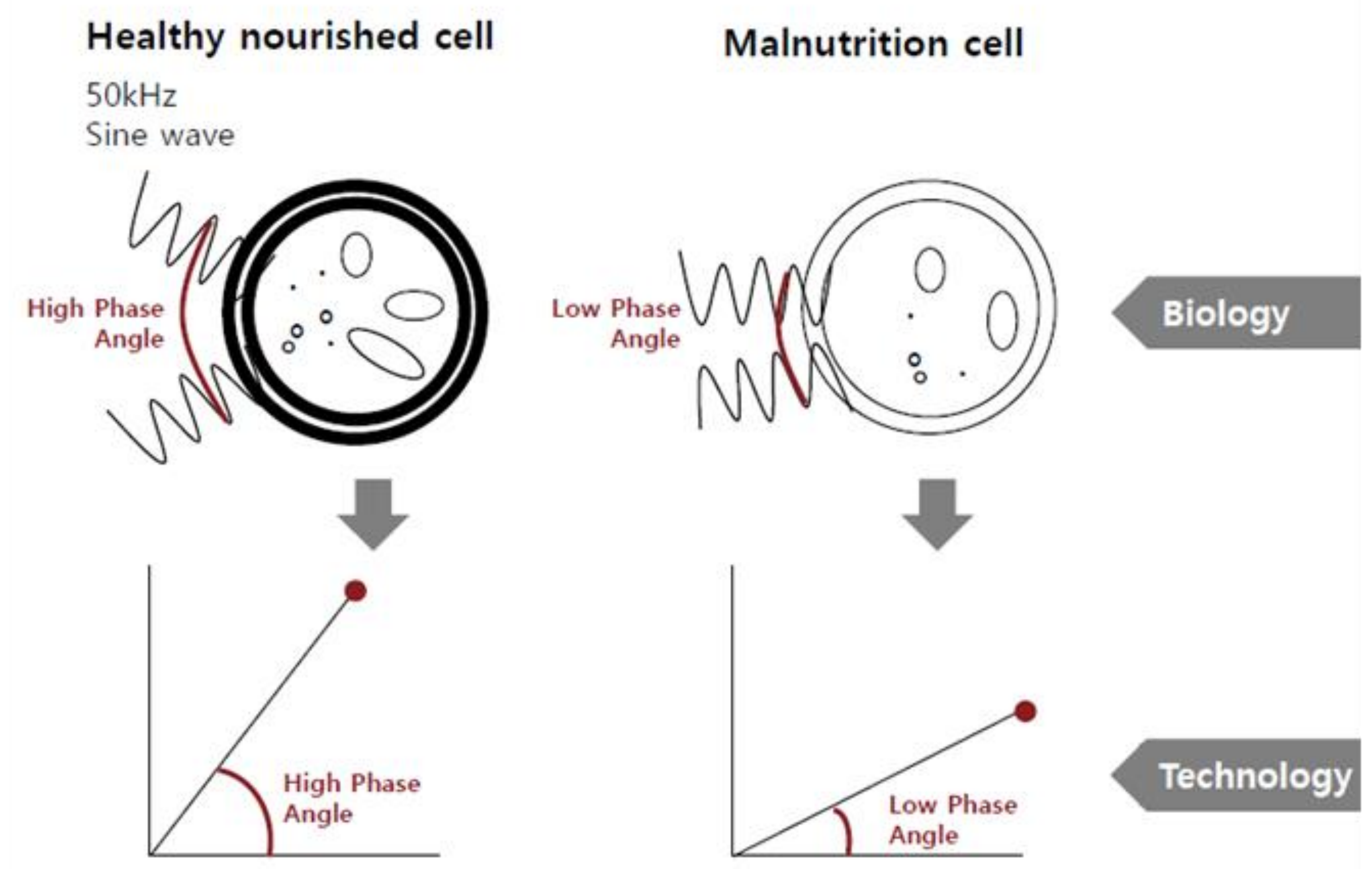
Segmental Phase Angle

2,1 °

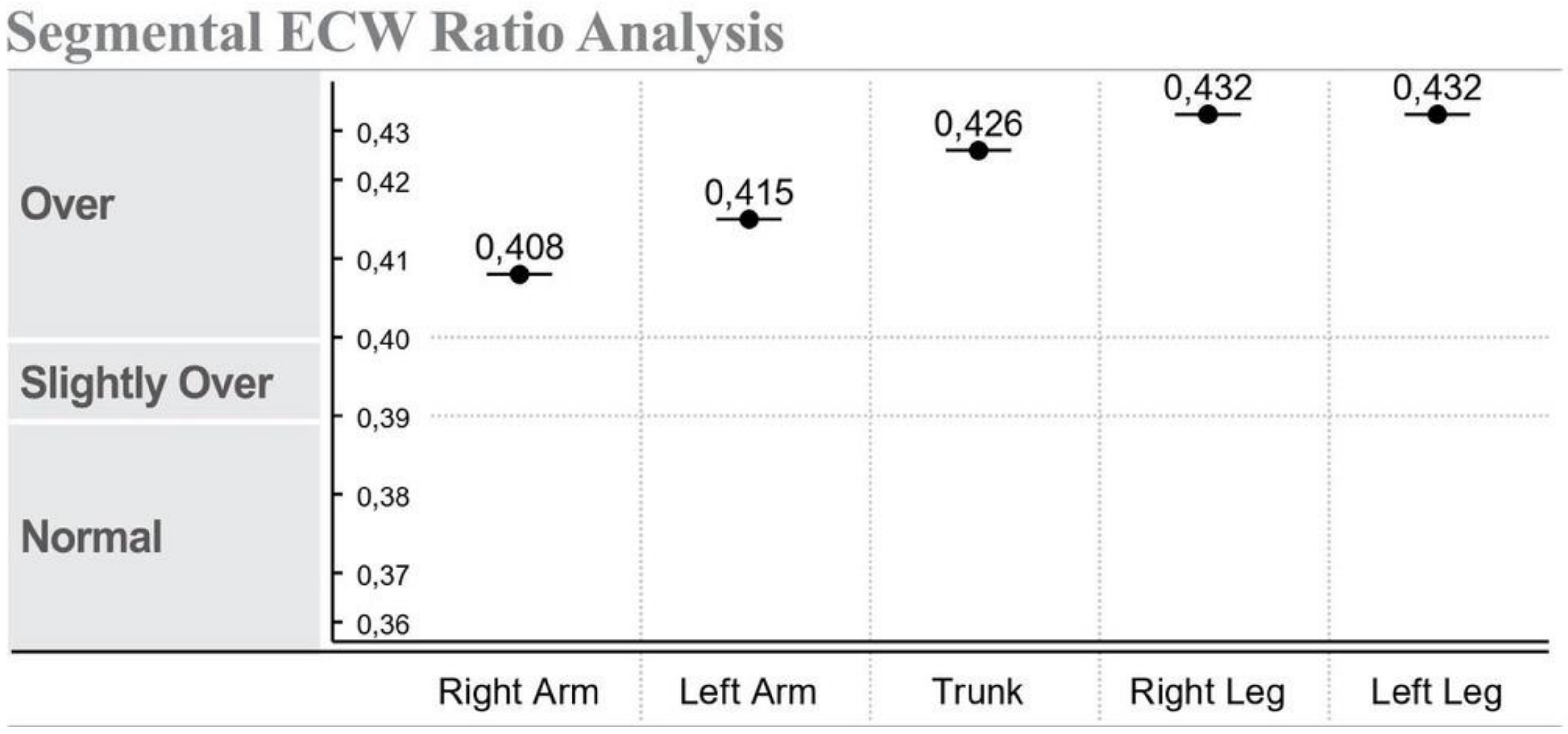
		RA	LA	TR	RL	LL
ϕ (°)	50 kHz	2,4	1,8	1,2	1,8	1,8

Intensity & Healthiness of cellular membrane makes Phase Angle higher, whereas malnutrition & aging can cause Phase Angle decreased.

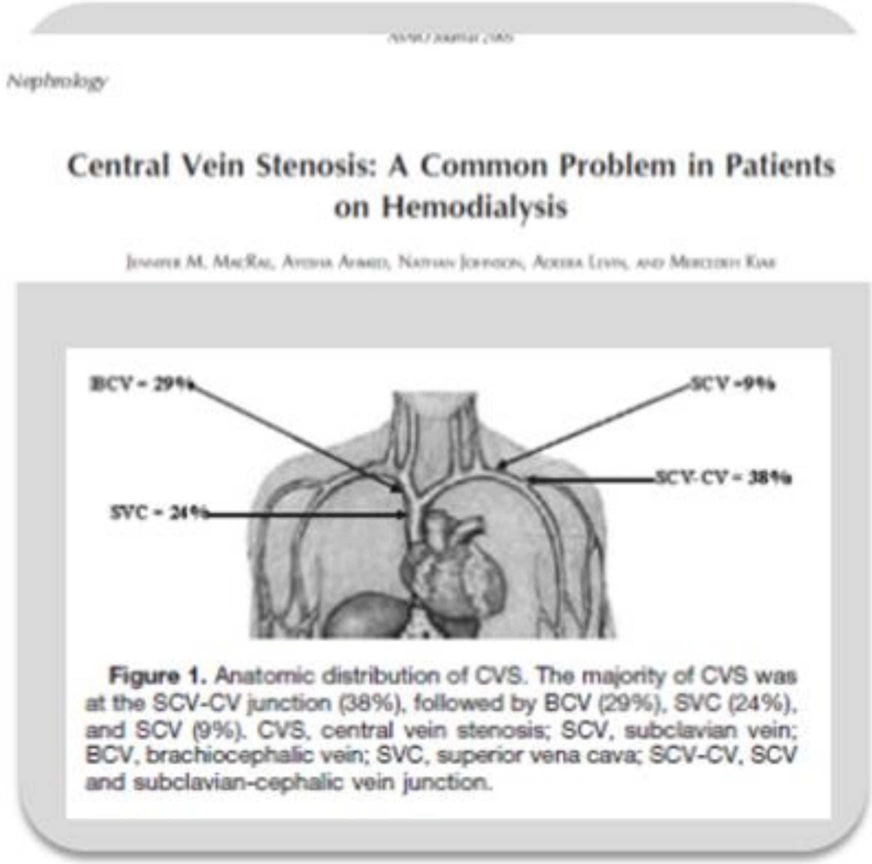




Circulation Check



Importance of management of Blood Circulation in HD Patients


Nephrology

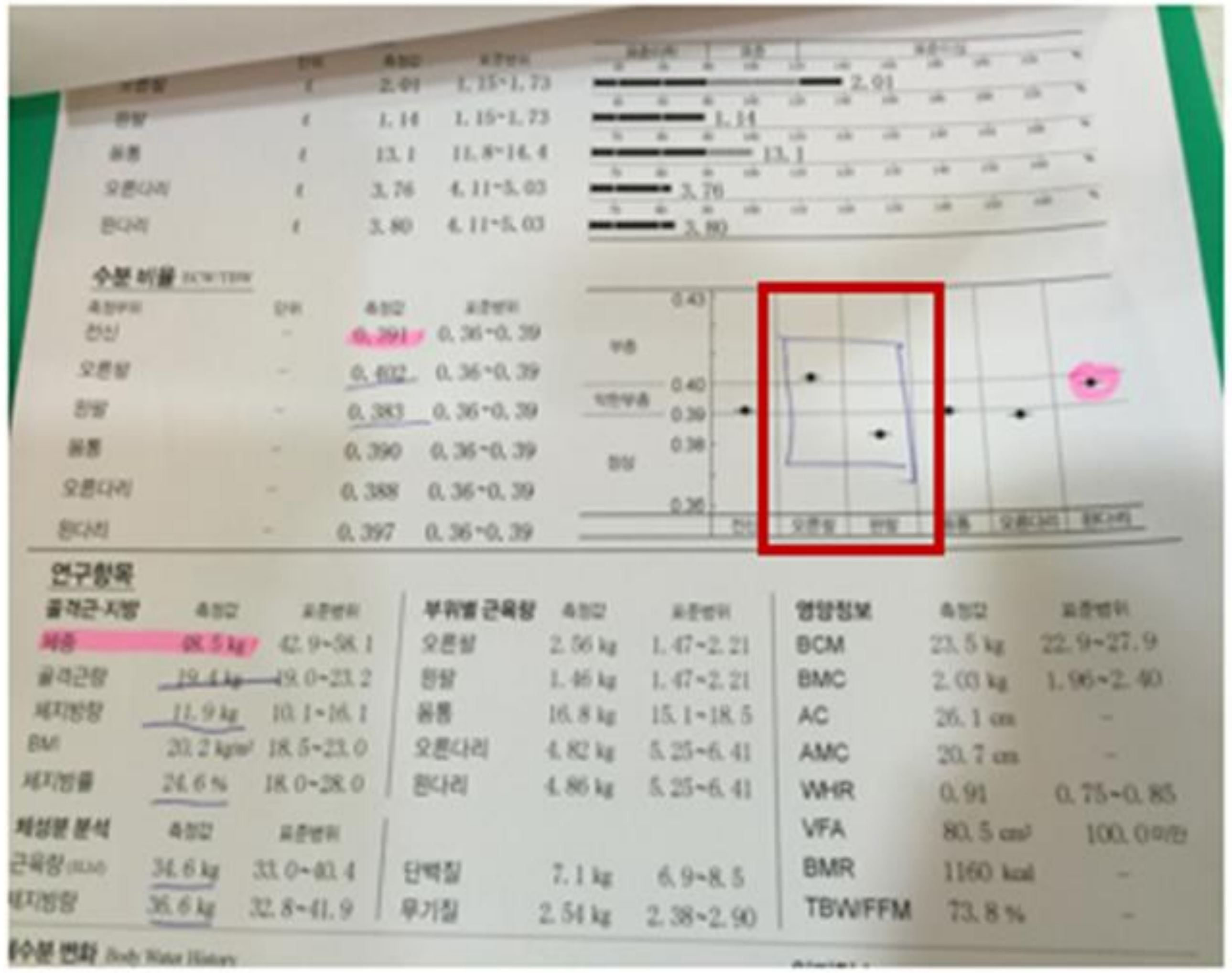
Central Vein Stenosis: A Common Problem in Patients on Hemodialysis

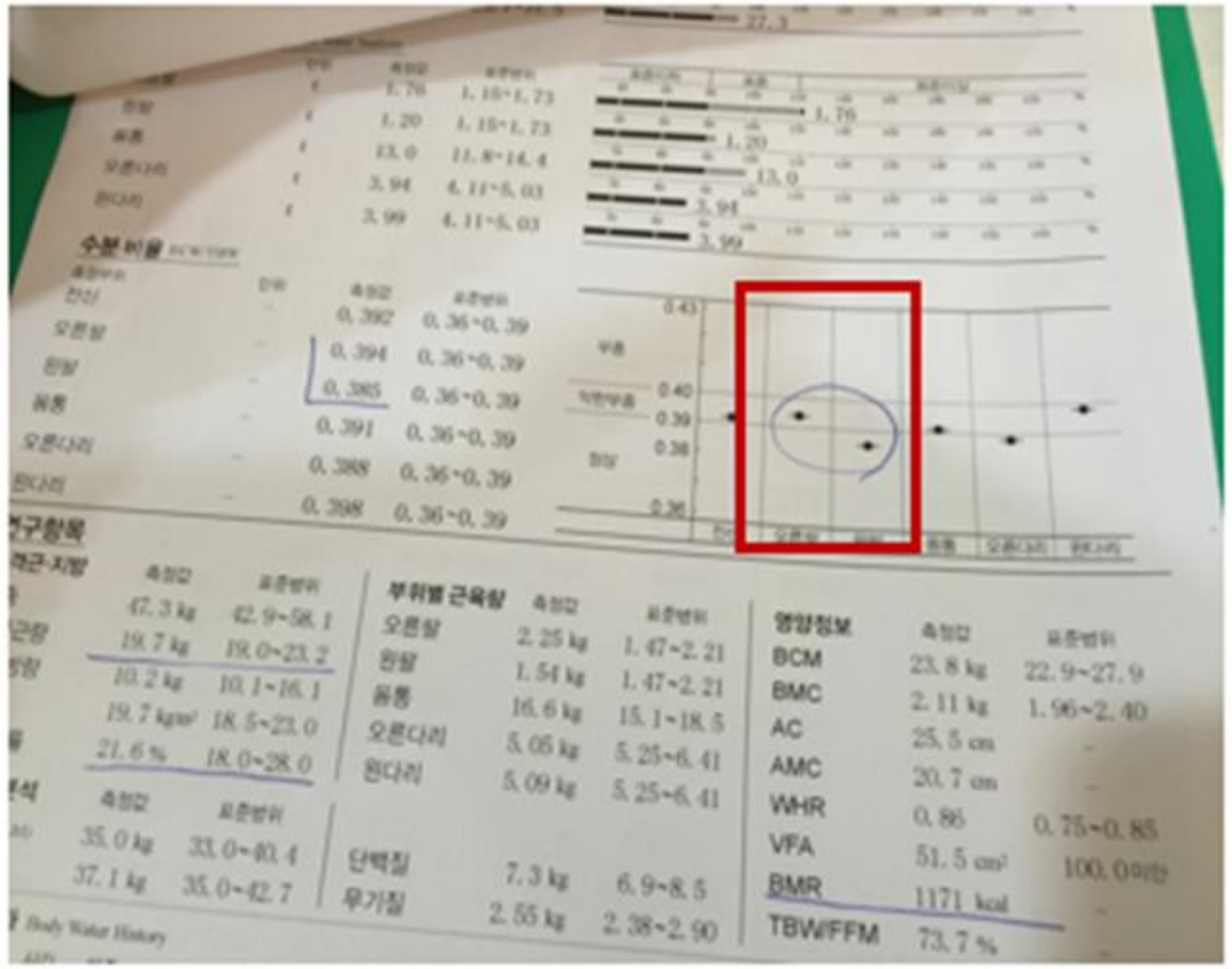
Figure 1. Anatomic distribution of CVS. The majority of CVS was at the SCV-CV junction (38%), followed by BCV (29%), SVC (24%), and SCV (9%). CVS, central vein stenosis; SCV, subclavian vein; BCV, brachiocephalic vein; SVC, superior vena cava; SCV-CV, SCV and subclavian-cephalic vein junction.

<u>Early detection of blood clot</u> could prevent further problems, but if failed to detect in early stage, it could cause blood vessel occlusion so that it needs to be cut out or inserted artificial blood vessel which will then need surgery.

Circulation Check

CVS(Central Vein Stenosis) Monitoring





RA: 0.402, LA: 0.383
→ 0.019 difference,

Blood Flow Meter Results → OK

⇨

Further Medical Check-up

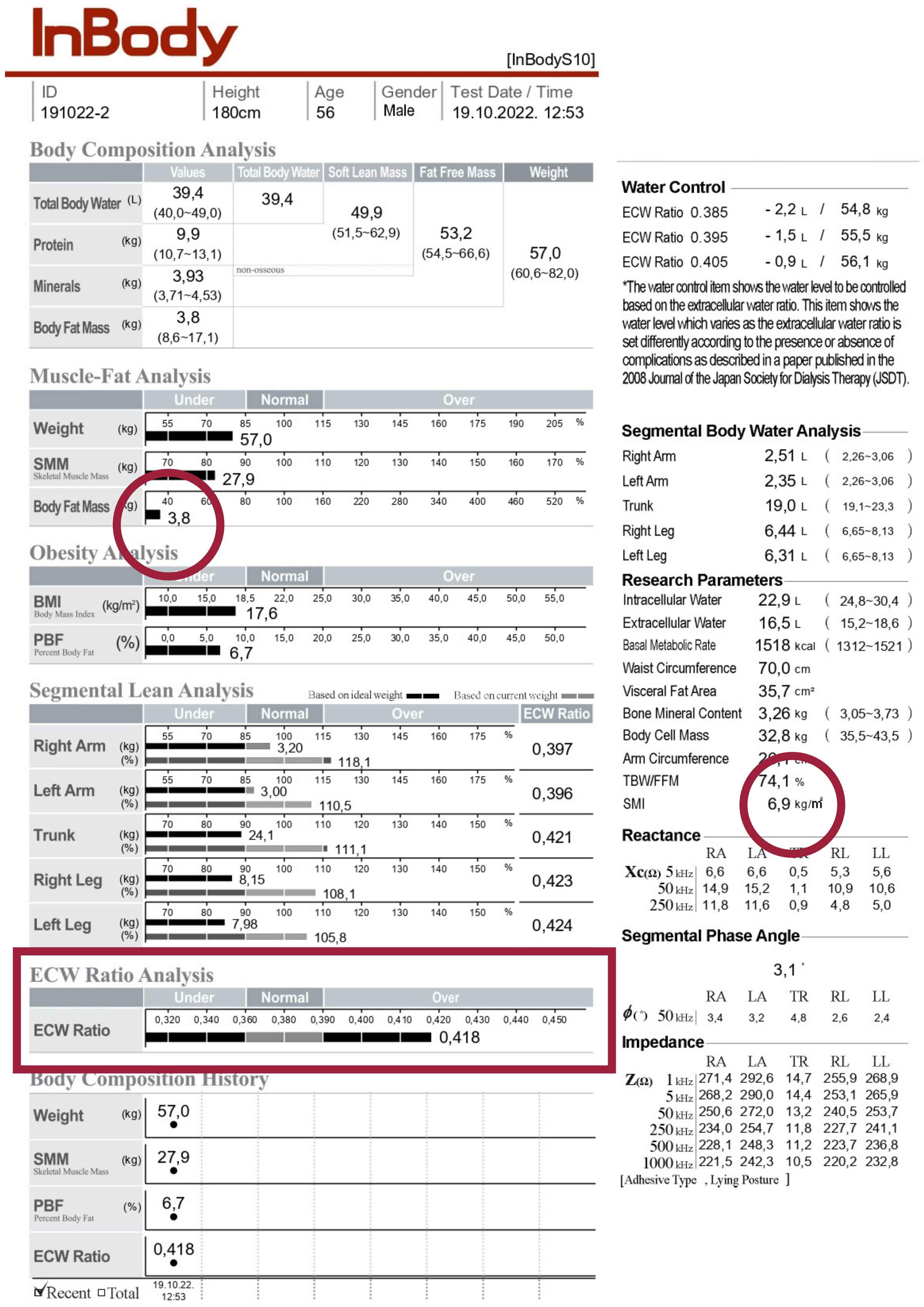
⇨

Blood Clot at RA in early stage & Surgery

⇨

Difference: 0.009

CASE 2



InBody [InBodyS10]

ID	Height	Age	Gender	Test Date / Time
191022-2	180cm	56	Male	19.10.2022. 12:53

Body Composition Analysis

	Values	Total Body Water	Soft Lean Mass	Fat Free Mass	Weight
Total Body Water (L)	39,4 (40,0~49,0)	39,4	49,9 (51,5~62,9)	53,2 (54,5~66,6)	57,0 (60,6~82,0)
Protein (kg)	9,9 (10,7~13,1)				
Minerals (kg)	3,93 (3,71~4,53)	non-osseous			
Body Fat Mass (kg)	3,8 (8,6~17,1)				

Muscle-Fat Analysis

	Value
Weight (kg)	57,0
SMM Skeletal Muscle Mass (kg)	27,9
Body Fat Mass (kg)	3,8

Obesity Analysis

	Value
BMI Body Mass Index (kg/m²)	17,6
PBF Percent Body Fat (%)	6,7

Segmental Lean Analysis (Based on ideal weight / Based on current weight)

	(kg)	(%)	ECW Ratio
Right Arm	3,20	118,1	0,397
Left Arm	3,00	110,5	0,396
Trunk	24,1	111,1	0,421
Right Leg	8,15	108,1	0,423
Left Leg	7,98	105,8	0,424

ECW Ratio Analysis

ECW Ratio: 0,418

Body Composition History

	19.10.22. 12:53
Weight (kg)	57,0
SMM Skeletal Muscle Mass (kg)	27,9
PBF Percent Body Fat (%)	6,7
ECW Ratio	0,418

☑Recent ☐Total

Water Control

ECW Ratio 0.385	- 2,2 L	54,8 kg
ECW Ratio 0.395	- 1,5 L	55,5 kg
ECW Ratio 0.405	- 0,9 L	56,1 kg

*The water control item shows the water level to be controlled based on the extracellular water ratio. This item shows the water level which varies as the extracellular water ratio is set differently according to the presence or absence of complications as described in a paper published in the 2008 Journal of the Japan Society for Dialysis Therapy (JSDT).

Segmental Body Water Analysis

Right Arm	2,51 L	(2,26~3,06)
Left Arm	2,35 L	(2,26~3,06)
Trunk	19,0 L	(19,1~23,3)
Right Leg	6,44 L	(6,65~8,13)
Left Leg	6,31 L	(6,65~8,13)

Research Parameters

Intracellular Water	22,9 L	(24,8~30,4)
Extracellular Water	16,5 L	(15,2~18,6)
Basal Metabolic Rate	1518 kcal	(1312~1521)
Waist Circumference	70,0 cm	
Visceral Fat Area	35,7 cm²	
Bone Mineral Content	3,26 kg	(3,05~3,73)
Body Cell Mass	32,8 kg	(35,5~43,5)
Arm Circumference	2[illegible] cm	
TBW/FFM	74,1 %	
SMI	6,9 kg/m²	

Reactance

Xc(Ω)	RA	LA	TR	RL	LL
5 kHz	6,6	6,6	0,5	5,3	5,6
50 kHz	14,9	15,2	1,1	10,9	10,6
250 kHz	11,8	11,6	0,9	4,8	5,0

Segmental Phase Angle

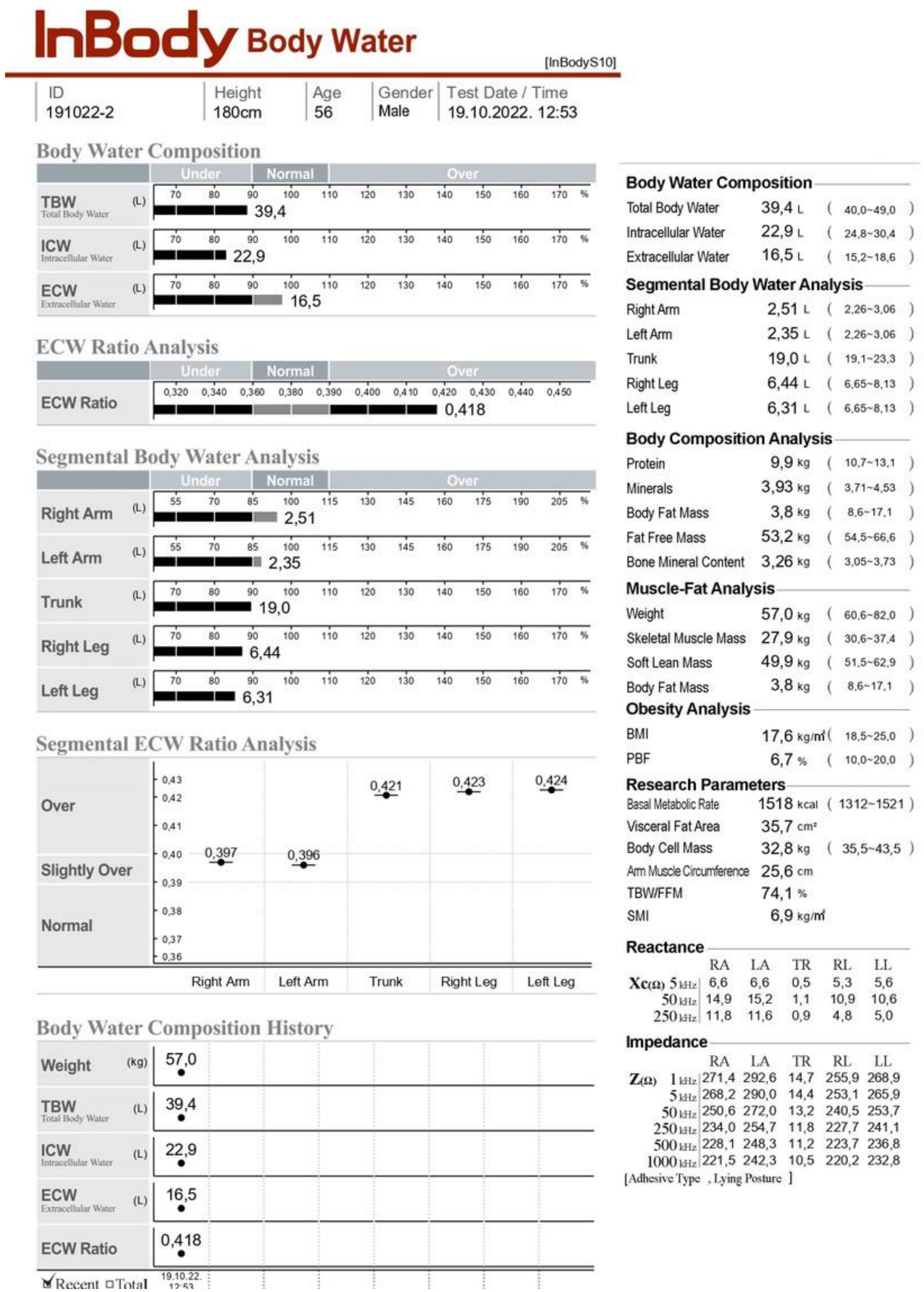
3,1°

ϕ(°)	RA	LA	TR	RL	LL
50 kHz	3,4	3,2	4,8	2,6	2,4

Impedance

Z(Ω)	RA	LA	TR	RL	LL
1 kHz	271,4	292,6	14,7	255,9	268,9
5 kHz	268,2	290,0	14,4	253,1	265,9
50 kHz	250,6	272,0	13,2	240,5	253,7
250 kHz	234,0	254,7	11,8	227,7	241,1
500 kHz	228,1	248,3	11,2	223,7	236,8
1000 kHz	221,5	242,3	10,5	220,2	232,8

[Adhesive Type , Lying Posture]



InBody Body Water [InBodyS10]

ID	Height	Age	Gender	Test Date / Time
191022-2	180cm	56	Male	19.10.2022. 12:53

Body Water Composition

	Value
TBW Total Body Water (L)	39,4
ICW Intracellular Water (L)	22,9
ECW Extracellular Water (L)	16,5

ECW Ratio Analysis

ECW Ratio: 0,418

Segmental Body Water Analysis

	(L)
Right Arm	2,51
Left Arm	2,35
Trunk	19,0
Right Leg	6,44
Left Leg	6,31

Segmental ECW Ratio Analysis

Right Arm	Left Arm	Trunk	Right Leg	Left Leg
0,397	0,396	0,421	0,423	0,424

(Over / Slightly Over / Normal)

Body Water Composition History

	19.10.22. 12:53
Weight (kg)	57,0
TBW Total Body Water (L)	39,4
ICW Intracellular Water (L)	22,9
ECW Extracellular Water (L)	16,5
ECW Ratio	0,418

☑Recent ☐Total

Body Water Composition

Total Body Water	39,4 L	(40,0~49,0)
Intracellular Water	22,9 L	(24,8~30,4)
Extracellular Water	16,5 L	(15,2~18,6)

Segmental Body Water Analysis

Right Arm	2,51 L	(2,26~3,06)
Left Arm	2,35 L	(2,26~3,06)
Trunk	19,0 L	(19,1~23,3)
Right Leg	6,44 L	(6,65~8,13)
Left Leg	6,31 L	(6,65~8,13)

Body Composition Analysis

Protein	9,9 kg	(10,7~13,1)
Minerals	3,93 kg	(3,71~4,53)
Body Fat Mass	3,8 kg	(8,6~17,1)
Fat Free Mass	53,2 kg	(54,5~66,6)
Bone Mineral Content	3,26 kg	(3,05~3,73)

Muscle-Fat Analysis

Weight	57,0 kg	(60,6~82,0)
Skeletal Muscle Mass	27,9 kg	(30,6~37,4)
Soft Lean Mass	49,9 kg	(51,5~62,9)
Body Fat Mass	3,8 kg	(8,6~17,1)

Obesity Analysis

BMI	17,6 kg/m²	(18,5~25,0)
PBF	6,7 %	(10,0~20,0)

Research Parameters

Basal Metabolic Rate	1518 kcal	(1312~1521)
Visceral Fat Area	35,7 cm²	
Body Cell Mass	32,8 kg	(35,5~43,5)
Arm Muscle Circumference	25,6 cm	
TBW/FFM	74,1 %	
SMI	6,9 kg/m²	

Reactance

Xc(Ω)	RA	LA	TR	RL	LL
5 kHz	6,6	6,6	0,5	5,3	5,6
50 kHz	14,9	15,2	1,1	10,9	10,6
250 kHz	11,8	11,6	0,9	4,8	5,0

Impedance

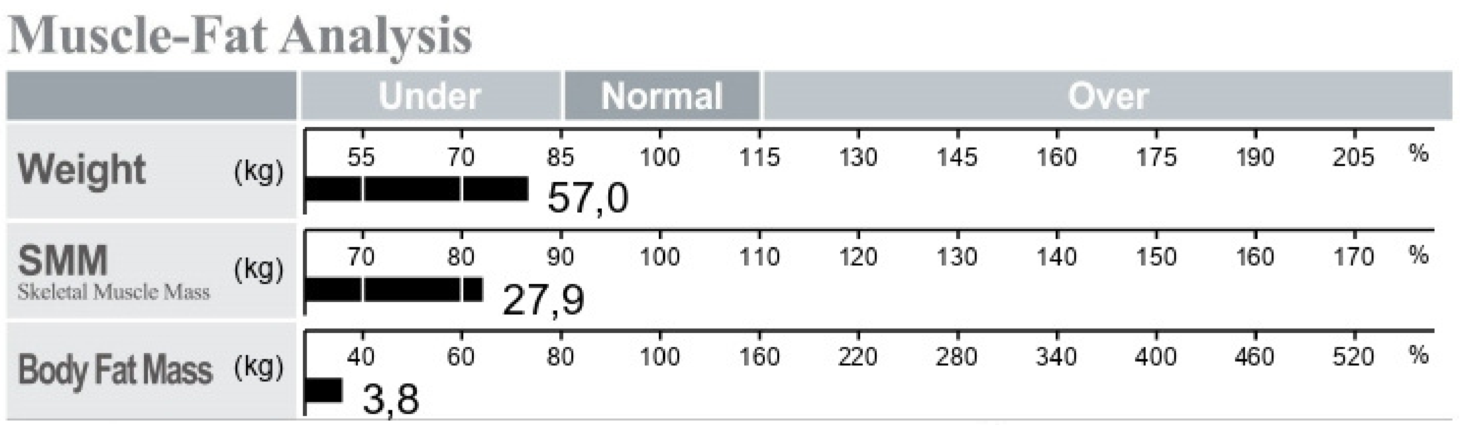
Z(Ω)	RA	LA	TR	RL	LL
1 kHz	271,4	292,6	14,7	255,9	268,9
5 kHz	268,2	290,0	14,4	253,1	265,9
50 kHz	250,6	272,0	13,2	240,5	253,7
250 kHz	234,0	254,7	11,8	227,7	241,1
500 kHz	228,1	248,3	11,2	223,7	236,8
1000 kHz	221,5	242,3	10,5	220,2	232,8

[Adhesive Type , Lying Posture]

Male, 56 years old, 180cm, 57.0kg, Blood Disorder, Ileostomy, Malnutrition

Sarcopenia

Muscle-Fat Analysis



SMI 6,9 kg/m²

Skeletal Muscle Index

Table 5. Diagnosis of sarcopenia: measurable variables and cut-off points

Criterion	Measurement method	Cut-off points by gender	Reference group defined	Ref
Muscle mass	DXA	Skeletal muscle mass index (SMI) (Appendicular skeletal muscle mass/height^2) Men: 7.26 kg/m^2 Women: 5.5 kg/m^2	Based on 2 SD below mean of young adults (Rosetta Study)	[66]
		SMI (ASM/height^2) Men: 7.25 kg/m^2 Women: 5.67 kg/m^2	Based on sex-specific lowest 20% of study group (n = 2,976)	[17]
		SMI (ASM/height^2) Men: 7.23 kg/m^2 Women: 5.67 kg/m^2	Based on sex-specific lowest 20% (Health ABC Study)	[68]
		Residuals of linear regression on appendicular lean mass adjusted for fat mass as well as height Men: −2.29 Women: −1.73	Based on sex-specific lowest 20% (Health ABC Study)	[68]
	BIA	SMI using BIA predicted skeletal muscle mass (SM) equation (SM/height^2) Men: 8.87 kg/m^2 Women: 6.42 kg/m^2	Based on 2 SD below mean of young adults in study group (n = 200)	[8]
		SMI using absolute muscle mass, not appendicular muscle mass (absolute muscle mass/height^2) Men: Severe sarcopenia ≤8.50 kg/m^2 Moderate sarcopenia 8.51–10.75 kg/m^2 Normal muscle ≥10.76 kg/m^2 Women: Severe sarcopenia ≤5.75 kg/m^2 Moderate sarcopenia 5.76–6.75 kg/m^2 Normal muscle ≥6.76 kg/m^2	Based on statistical analysis of NHANES III data on older (≥60 years) men and women	[19, 67]

Diagnosis of Sarcopenia Cut-Off
Male: 8.87kg/m²
Female: 6.42kg/m²

SMI (by InBody)

研究項目 Research Parameters
骨格筋量 19.6 kg (19.5～23.9)

Skeletal Muscle Mass (SMM)

Impact of Sarcopenia on Survival in Patients Undergoing Living Donor Liver Transplantation

T. Kaido*, K. Ogawa, Y. Fujimoto, Y. Ogura, K. Hata, T. Ito, K. Tomiyama, S. Yagi, A. Mori and S. Uemoto

Division of Hepato-Biliary-Pancreatic and Transplant Surgery, Department of Surgery, Graduate School of Medicine, Kyoto University, Kyoto, Japan

American Journal of Transplantation 2013; XX: 1–8

Absolute evaluation on standard weight

Male Standard WT×47% Female Standard WT×42%

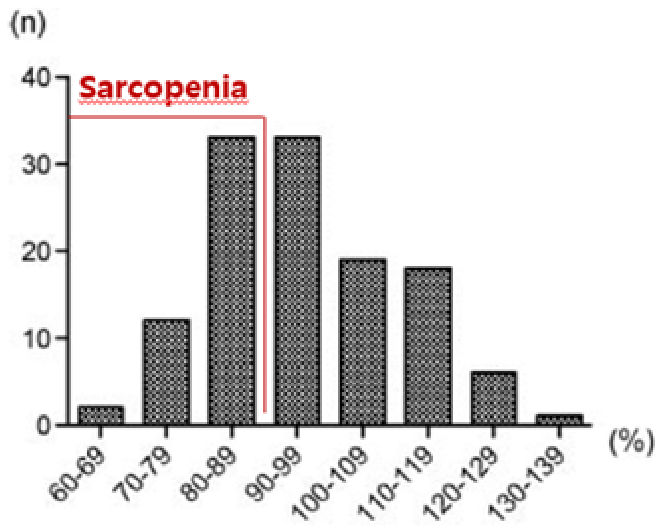
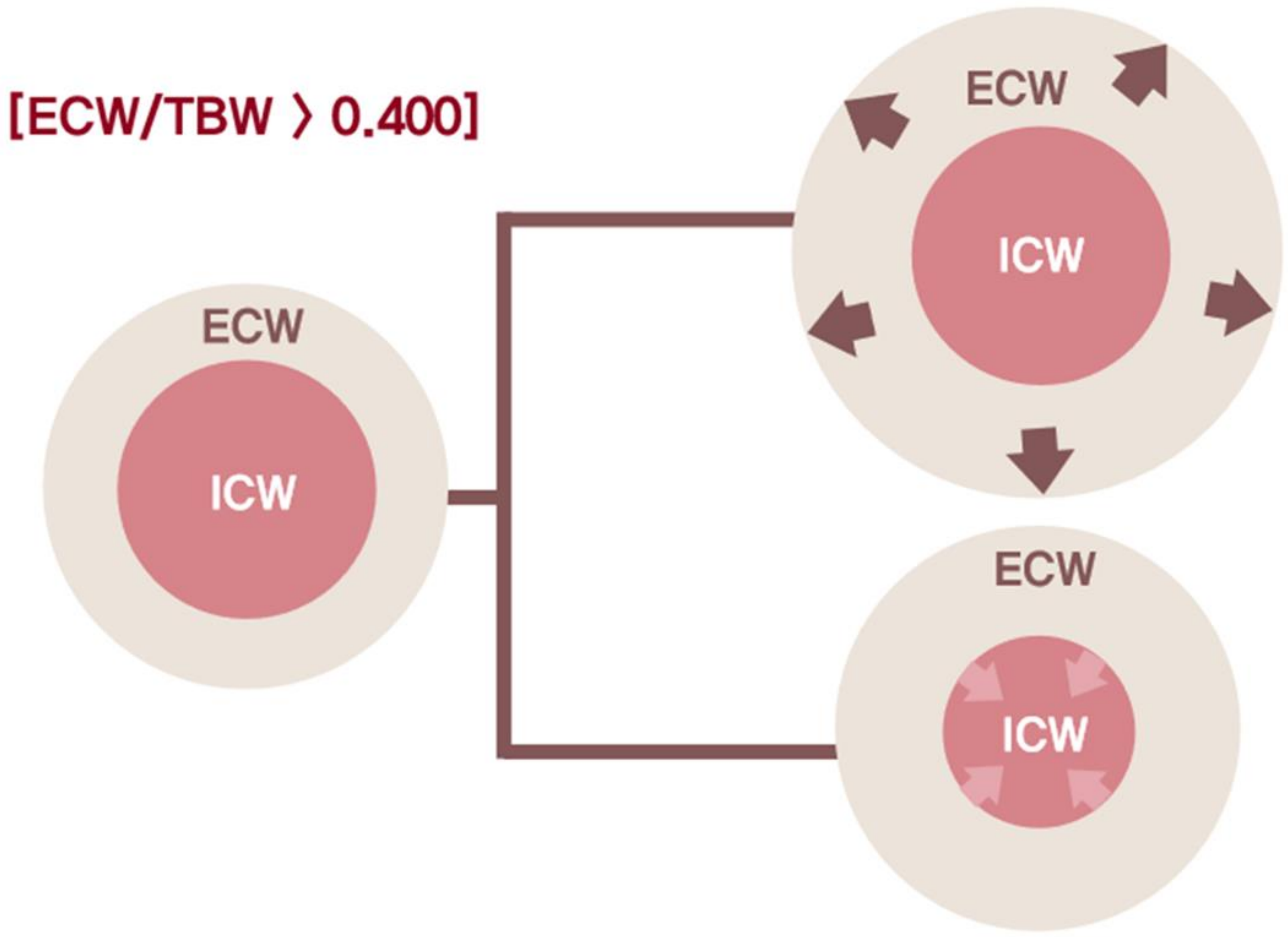


Figure 1: Ratios of the skeletal muscle mass values to the standard mass on admission.

Heymsfield SB, Smith R, Aulet M, Bensen B, Lichtman S, Wang J, Pierson RN Jr. Appendicular skeletal muscle mass: measurement by dual-photon absorptiometry. Am J Clin Nutr. 52(2):214-8, 1990

Sarcopenia



[Case 1. Increase in ECW]

Acute Kidney Failure
Kidney Disease
After Sugery
etc

[Case 2. Decrease in ICW]

Malnutrition
Aging
Cachexia
ALS
etc

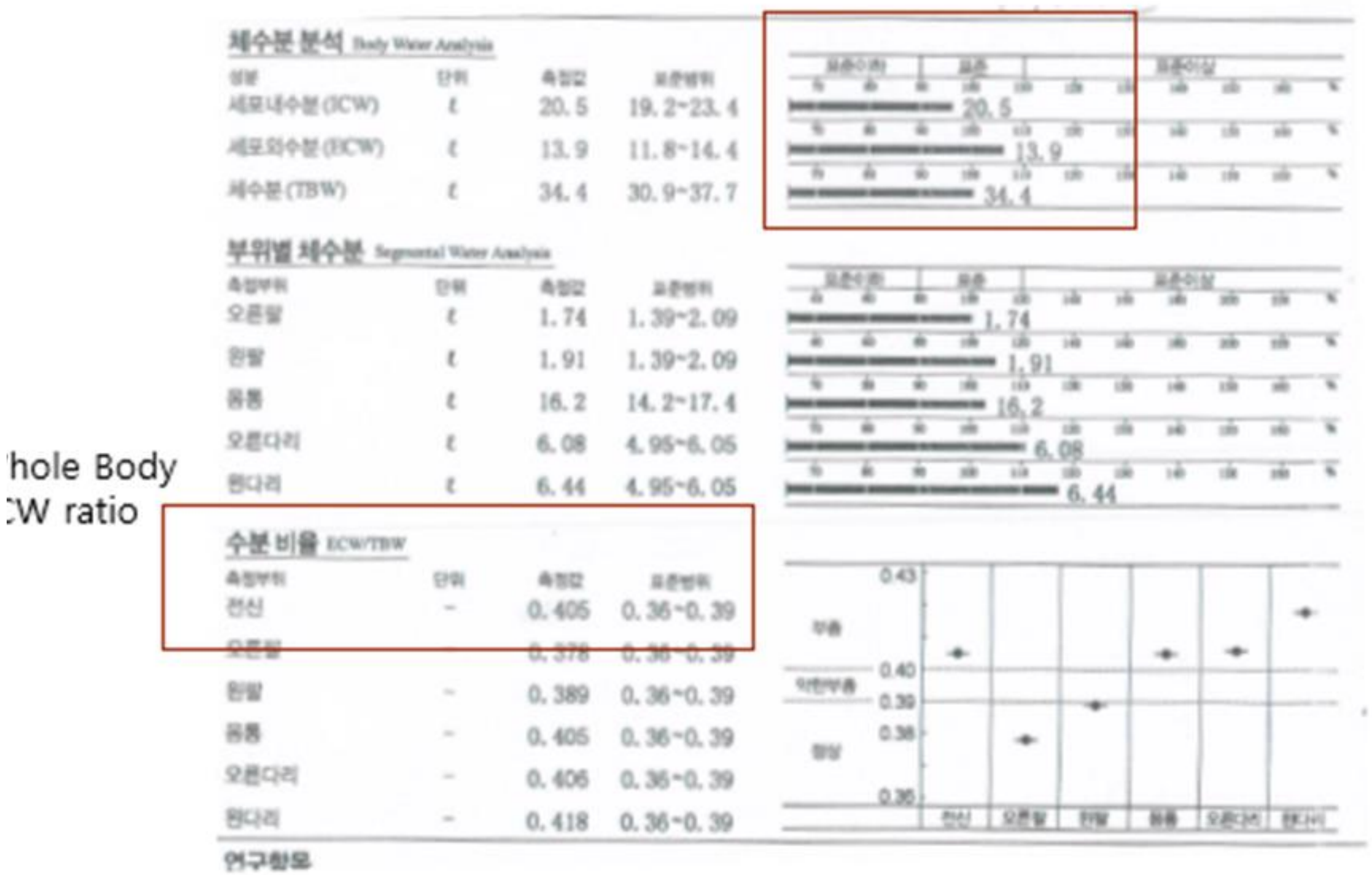
2 Possible causes for increase in ECW ratio

Sarcopenia

Interpretation of cases with ECW/TBW>0.400

When Extracellular water(ECW) increase is the cause

170㎝ / Female / DM



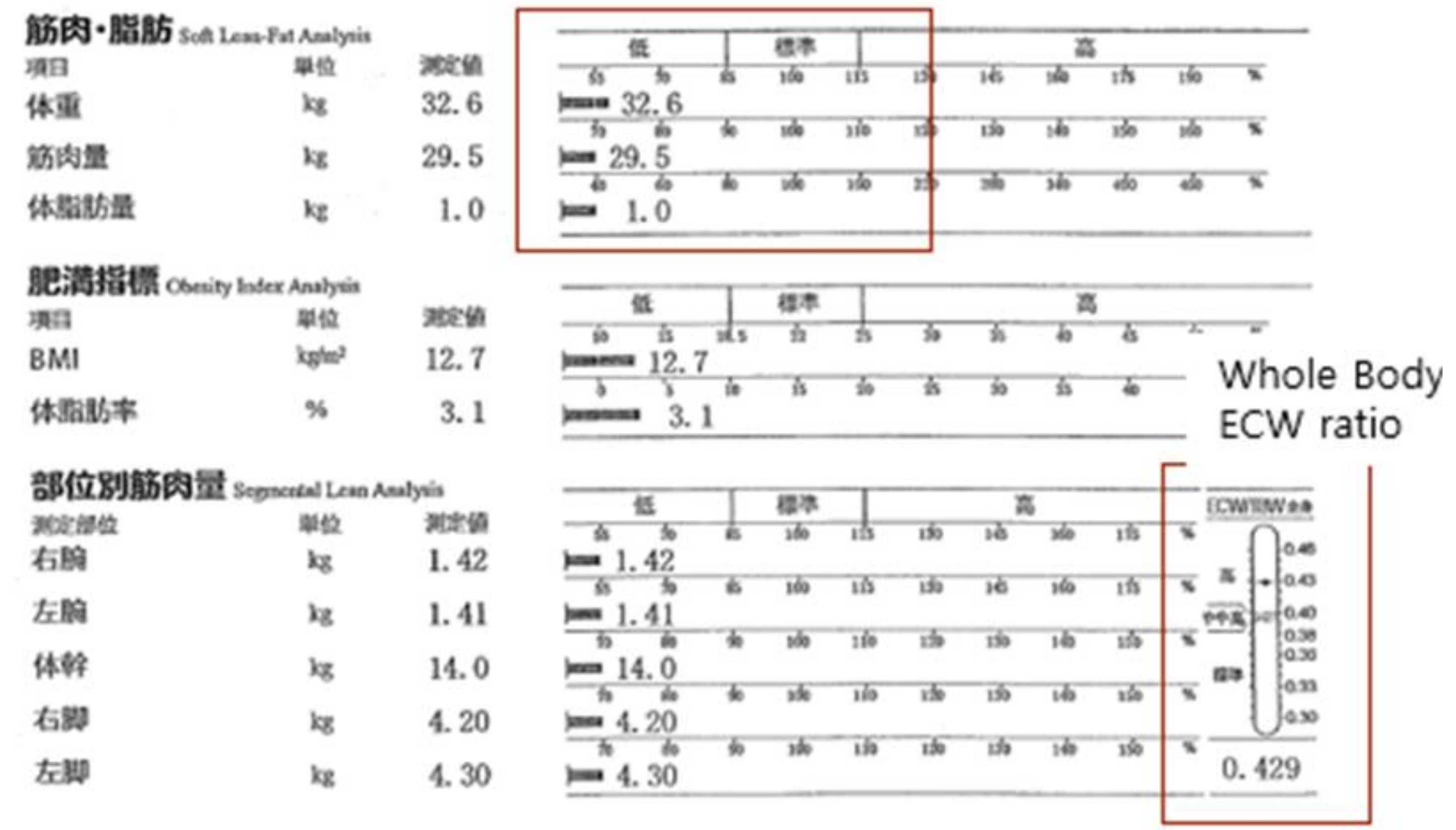
SMI 9.51kg/m², ECW/TBW 0.447 Overhydrated Status

Need to improve edema first!

Meaningless for evaluating SMI

When Intracellular water(ICW) decrease is the cause

160㎝ / Male / Muscular dystrophy & Dilated cardiomyopathy



SMI 4.43kg/m², ECW/TBW 0.429 Overhydrated Status

Nutrition status is very serious

OK to evaluate SMI

Diagnosis of Sarcopenia
Male: 8.87kg/m²
Female: 6.42kg/m²

Sarcopenia

Review Article

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pISSN 2289-0203 · eISSN 2383-7101
http://dx.doi.org/10.15747/jcn.2015.7.1.9

중환자 영양치료를 위한 생체전기저항분석법의 활용

이연희[1], 이재명[2]
[1]아주대학교병원 영양팀, [2]아주대학교 의과대학 외과학교실

Use of Bioelectrical Impedance Analysis for Nutritional Treatment in Critically Ill Patients

Yeon Hee Lee[1] and Jae Myeong Lee[2]
[1]Food Service and Clinical Nutrition Team, Ajou University Hospital, [2]Department of Surgery, Ajou University School of Medicine, Suwon, Korea

Patients in the intensive care unit (ICU) easily have large amounts of extracellular fluids, such as edema or ascites, because of cardiovascular instability under septic conditions and also have high risk of malnutrition while staying in the ICU. Traditional nutritional assessment parameters like body mass index have a limitation in ICU patients due to muscle atrophy and decrease of lean body mass. Bioimpedence analyses (BIA) can be used to assess body composition and are useful in performance of nutritional assessments in ICU patients. BIA can simply and noninvasively estimate body composition (total body water, extracellular water, intracellular water, body cell mass, and free fat mass etc.) by sending a weak electric current through the body. In particular, phase angle (PhA, phase difference between the voltage applied to the impedance and the current driven through it), one of the parameters of BIA, is related to cell membrane integrity or cell size. Low PhA can possibly imply malnutrition and PhA has been reported as a useful indicator of clinical outcomes or prognosis of severe patients. Additional study with clinical application of BIA in ICU patients is needed in order to confirm the usefulness of BIA.

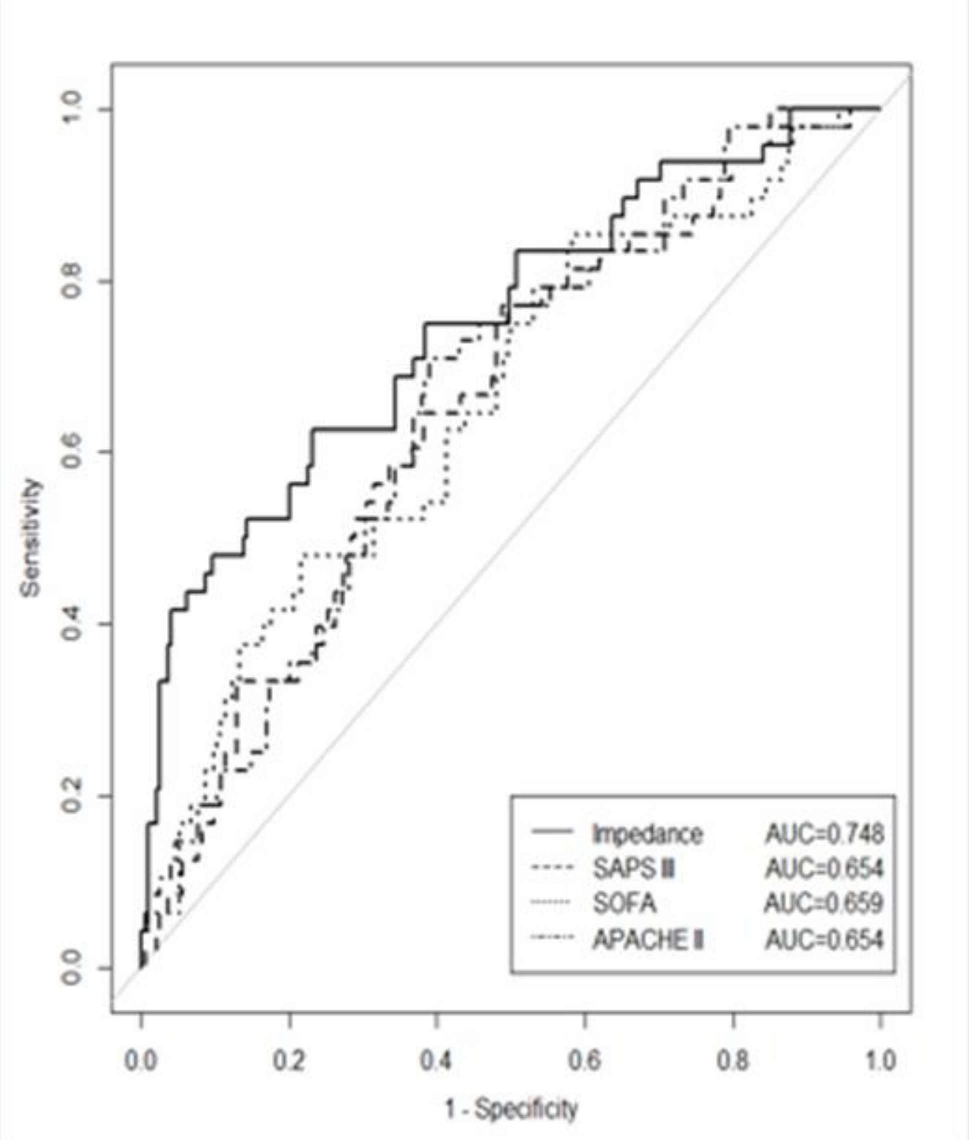


Fig. 1. Covariate-adjusted ROC curves for BIA values (Reactance, Impedance and Wholebody phase angle) and severity scorings (APACHE II, SOFA, and SAPS III) as mortality predictive tools. (Adjusted values; age, gender, BMI)

CASE 3

InBody

[InBodyS10]

ID	Height	Age	Gender	Test Date / Time
191022-3	185cm	54	Male	19.10.2022. 13:21

Body Composition Analysis

	Values	Total Body Water	Soft Lean Mass	Fat Free Mass	Weight
Total Body Water (L)	47,7 (42,3~51,7)	47,7	60,9 (54,4~66,4)	64,5 (57,6~70,4)	90,0 (64,0~86,6)
Protein (kg)	12,4 (11,3~13,9)				
Minerals (kg)	4,37 (3,91~4,78)	non-osseous			
Body Fat Mass (kg)	25,5 (9,0~18,1)				

Muscle-Fat Analysis

	Under / Normal / Over	
Weight (kg)	55 70 85 100 115 130 145 160 175 190 205 %	90,0
SMM Skeletal Muscle Mass (kg)	70 80 90 100 110 120 130 140 150 160 170 %	35,5
Body Fat Mass (kg)	40 60 80 100 160 220 280 340 400 460 520 %	25,5

Obesity Analysis

	Under / Normal / Over	
BMI Body Mass Index (kg/m²)	10,0 15,0 18,5 22,0 25,0 30,0 35,0 40,0 45,0 50,0 55,0	26,3
PBF Percent Body Fat (%)	0,0 5,0 10,0 15,0 20,0 25,0 30,0 35,0 40,0 45,0 50,0	28,3

Segmental Lean Analysis

Based on ideal weight / Based on current weight

	Under / Normal / Over	(kg)	(%)	ECW Ratio
Right Arm	55 70 85 100 115 130 145 160 175 %	4,01	106,3	0,368
Left Arm	55 70 85 100 115 130 145 160 175 %	3,89	103,2	0,375
Trunk	70 80 90 100 110 120 130 140 150 %	30,1	100,2	0,396
Right Leg	70 80 90 100 110 120 130 140 150 %	10,31	98,4	0,395
Left Leg	70 80 90 100 110 120 130 140 150 %	10,21	97,4	0,420

ECW Ratio Analysis

	Under / Normal / Over	
ECW Ratio	0,320 0,340 0,360 0,380 0,390 0,400 0,410 0,420 0,430 0,440 0,450	0,397

Body Composition History

		19.10.22. 13:21
Weight	(kg)	90,0
SMM Skeletal Muscle Mass	(kg)	35,5
PBF Percent Body Fat	(%)	28,3
ECW Ratio		0,397

☑Recent ☐Total

Water Control

ECW Ratio 0.385	- 0,9 L	/ 89,1 kg
ECW Ratio 0.395	- 0,1 L	/ 89,9 kg
ECW Ratio 0.405	+ 0,7 L	/ 90,7 kg

*The water control item shows the water level to be controlled based on the extracellular water ratio. This item shows the water level which varies as the extracellular water ratio is set differently according to the presence or absence of complications as described in a paper published in the 2008 Journal of the Japan Society for Dialysis Therapy (JSDT).

Segmental Body Water Analysis

Right Arm	3,11 L	(2,39~3,23)
Left Arm	3,02 L	(2,39~3,23)
Trunk	23,6 L	(20,2~24,6)
Right Leg	8,07 L	(7,03~8,59)
Left Leg	8,06 L	(7,03~8,59)

Research Parameters

Intracellular Water	28,8 L	(26,3~32,1)
Extracellular Water	18,9 L	(16,1~19,7)
Basal Metabolic Rate	1764 kcal	(1857~2188)
Waist Circumference	105,4 cm	
Visceral Fat Area	131,5 cm²	
Bone Mineral Content	3,59 kg	(3,22~3,94)
Body Cell Mass	41,2 kg	(37,6~46,0)
Arm Circumference	35,3 cm	
TBW/FFM	74,0 %	
SMI	8,3 kg/m²	

Reactance

Xc(Ω)	RA	LA	TR	RL	LL
5 kHz	16,7	18,6	1,9	13,6	9,0
50 kHz	32,3	22,5	3,3	22,2	12,7
250 kHz	28,8	21,1	1,9	11,4	9,2

Segmental Phase Angle

6,6 °

	RA	LA	TR	RL	LL
ϕ(°) 50 kHz	7,7	5,2	8,9	5,3	3,0

Impedance

Z(Ω)	RA	LA	TR	RL	LL
1 kHz	291,4	299,1	26,9	279,0	266,2
5 kHz	282,0	281,0	26,2	269,2	257,8
50 kHz	240,9	247,8	21,1	240,0	243,5
250 kHz	209,5	220,1	17,6	218,4	229,8
500 kHz	198,0	207,8	16,2	212,7	224,4
1000 kHz	181,7	192,4	14,0	206,9	218,8

[Adhesive Type , Lying Posture]

InBody Body Water

[InBodyS10]

ID	Height	Age	Gender	Test Date / Time
191022-3	185cm	54	Male	19.10.2022. 13:21

Body Water Composition

	Under / Normal / Over	
TBW Total Body Water (L)	70 80 90 100 110 120 130 140 150 160 170 %	47,7
ICW Intracellular Water (L)	70 80 90 100 110 120 130 140 150 160 170 %	28,8
ECW Extracellular Water (L)	70 80 90 100 110 120 130 140 150 160 170 %	18,9

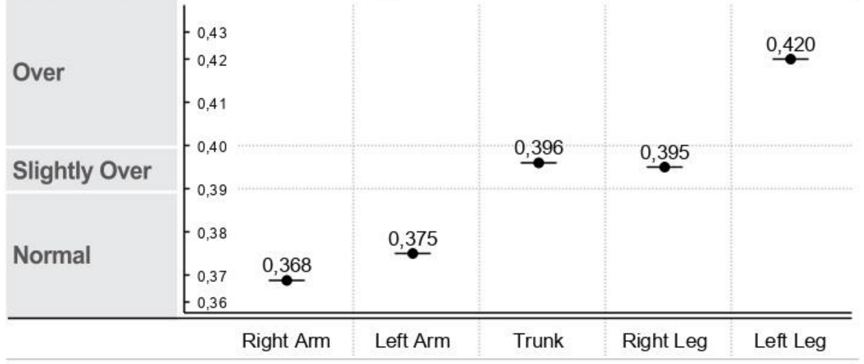
ECW Ratio Analysis

	Under / Normal / Over	
ECW Ratio	0,320 0,340 0,360 0,380 0,390 0,400 0,410 0,420 0,430 0,440 0,450	0,397

Segmental Body Water Analysis

	Under / Normal / Over	
Right Arm (L)	55 70 85 100 115 130 145 160 175 190 205 %	3,11
Left Arm (L)	55 70 85 100 115 130 145 160 175 190 205 %	3,02
Trunk (L)	70 80 90 100 110 120 130 140 150 160 170 %	23,6
Right Leg (L)	70 80 90 100 110 120 130 140 150 160 170 %	8,07
Left Leg (L)	70 80 90 100 110 120 130 140 150 160 170 %	8,06

Segmental ECW Ratio Analysis



Body Water Composition History

		19.10.22. 13:21
Weight	(kg)	90,0
TBW Total Body Water	(L)	47,7
ICW Intracellular Water	(L)	28,8
ECW Extracellular Water	(L)	18,9
ECW Ratio		0,397

☑Recent ☐Total

Body Water Composition

Total Body Water	47,7 L	(42,3~51,7)
Intracellular Water	28,8 L	(26,3~32,1)
Extracellular Water	18,9 L	(16,1~19,7)

Segmental Body Water Analysis

Right Arm	3,11 L	(2,39~3,23)
Left Arm	3,02 L	(2,39~3,23)
Trunk	23,6 L	(20,2~24,6)
Right Leg	8,07 L	(7,03~8,59)
Left Leg	8,06 L	(7,03~8,59)

Body Composition Analysis

Protein	12,4 kg	(11,3~13,9)
Minerals	4,37 kg	(3,91~4,78)
Body Fat Mass	25,5 kg	(9,0~18,1)
Fat Free Mass	64,5 kg	(57,6~70,4)
Bone Mineral Content	3,59 kg	(3,22~3,94)

Muscle-Fat Analysis

Weight	90,0 kg	(64,0~86,6)
Skeletal Muscle Mass	35,5 kg	(32,4~39,6)
Soft Lean Mass	60,9 kg	(54,4~66,4)
Body Fat Mass	25,5 kg	(9,0~18,1)

Obesity Analysis

BMI	26,3 kg/m²	(18,5~25,0)
PBF	28,3 %	(10,0~20,0)

Research Parameters

Basal Metabolic Rate	1764 kcal	(1857~2188)
Visceral Fat Area	131,5 cm²	
Body Cell Mass	41,2 kg	(37,6~46,0)
Arm Muscle Circumference	31,6 cm	
TBW/FFM	74,0 %	
SMI	8,3 kg/m²	

Reactance

Xc(Ω)	RA	LA	TR	RL	LL
5 kHz	16,7	18,6	1,9	13,6	9,0
50 kHz	32,3	22,5	3,3	22,2	12,7
250 kHz	28,8	21,1	1,9	11,4	9,2

Impedance

Z(Ω)	RA	LA	TR	RL	LL
1 kHz	291,4	299,1	26,9	279,0	266,2
5 kHz	282,0	281,0	26,2	269,2	257,8
50 kHz	240,9	247,8	21,1	240,0	243,5
250 kHz	209,5	220,1	17,6	218,4	229,8
500 kHz	198,0	207,8	16,2	212,7	224,4
1000 kHz	181,7	192,4	14,0	206,9	218,8

[Adhesive Type , Lying Posture]

Male, 56 years old, 180cm, 56.0kg, Gunshot wound, open abdomen, stroke and hemiplegia

Phase Angle

Segmental Phase Angle

6,6 °

		RA	LA	TR	RL	LL
ϕ (°)	50 kHz	7,7	5,2	8,9	5,3	3,0

Phase Angle as an Indicator of Baseline Nutritional Status and Sarcopenia in Acute Stroke

Yoichi Sato [1], Yoshihiro Yoshimura [2], Takafumi Abe [1]

Affiliations + expand

PMID: 34826661 DOI: 10.1016/j.jstrokecerebrovasdis.2021.106220

Abstract

Objectives: This study aimed to investigate whether phase angle is an indicator of malnutrition and sarcopenia in acute-phase stroke patients.

Materials and methods: We conducted a retrospective observational study of stroke patients in a single acute-care hospital. The phase angle was measured within 5 days after admission, and the correlation between nutritional status and sarcopenia index was investigated. The cut-off point that distinguishes malnutrition and sarcopenia was evaluated using the receiver operating characteristic curve. The effects of the geriatric nutritional risk index (GNRI) and sarcopenia on the phase angle were examined using multivariate linear regression analysis.

Results: A total of 211 stroke patients (140 men) with a median age of 74 (65-83) were included in the analysis. Malnutrition was present in 38 (18.0%) patients, and 65 (30.8%) had sarcopenia. The phase angle significantly correlated with GNRI, grip strength, skeletal muscle musss index, and calf circumference in both men and women. The cut-off points for discriminating malnutrition were 5.05 for men and 3.96 for women, while the cut-off points for discriminating sarcopenia were 5.28 for men and 4.62 for women. Multivariate linear regression analysis showed that the GNRI and sarcopenia were independently related to the phase angle.

Conclusions: Phase angle is a useful indicator for distinguishing malnutrition and sarcopenia in patients with acute stroke.

Mortality of Critical Care Patients and relation with ECW/TBW, Phase angle

Use of Bioelectrical Impedance Analysis for the Assessment of Nutritional Status in Critically Ill Patients

Yoojin Lee[1], Oran Kwon[1], Cheung Soo Shin[2], Song Mi Lee[3*]

[1]Department of Clinical Health, Graduate School of Clinical Health Sciences, Ewha Woman's University, Seoul 120-750, Korea
[2]Department of Anesthesiology and Pain Medicine, Yonsei University College of Medicine, Seoul 135-720, Korea
[3]Department of Nutrition Services, Gangnam Severance Hospital, Seoul 135-720, Korea

Table 5. Comparison of BMI, biochemical data, and BIA data between survivors and non-survivors

	Variables	Non-survivors (n = 8)	Survivors (n = 58)	p value
BMI	BMI, kg/m^2	22.7 ± 2.3*	23.7 ± 3.5	0.30
Bio-chemical data	Albumin, g/dL	3.0 ± 0.3	3.3 ± 0.6	0.06
	TLC, cells/mm^3	616.3 ± 330.9	1039.7 ± 663.4	0.01‡
	Hemoglobin, g/dL	10.8 ± 1.5	10.8 ± 1.7	0.89
BIA data	PhA, °	2.9 ± 0.8	4.1 ± 1.2	< 0.01†
	Total body water (TBW), L	35.7 ± 3.8	35.6 ± 7.8	0.95
	ECW/TBW	0.42 ± 0.01	0.40 ± 0.02	< 0.01†
	%Body fat (%BF), %	25.3 ± 11.0	25.0 ± 10.8	0.95
	Skeletal muscle mass (SMM), kg	24.1 ± 2.7	25.8 ± 6.3	0.23
	Body cell mass (BCM), kg	28.7 ± 3.0	30.4 ± 6.9	0.28

BMI: body mass index, TLC: total lymphocyte count, BIA: bioelectrical impedance analysis, PhA: phase angle, ECW/TBW: extracellular water/total body water, TBW/FFM: total body water/fat free mass.
*Mean ± Standard Deviation; †$p < 0.01$; ‡$p < 0.05$

Clin Nutr Res 2015

Phase angle and **ECW Ratio** measured by BIA, can be used for **Critically ill patient's** nutritional status

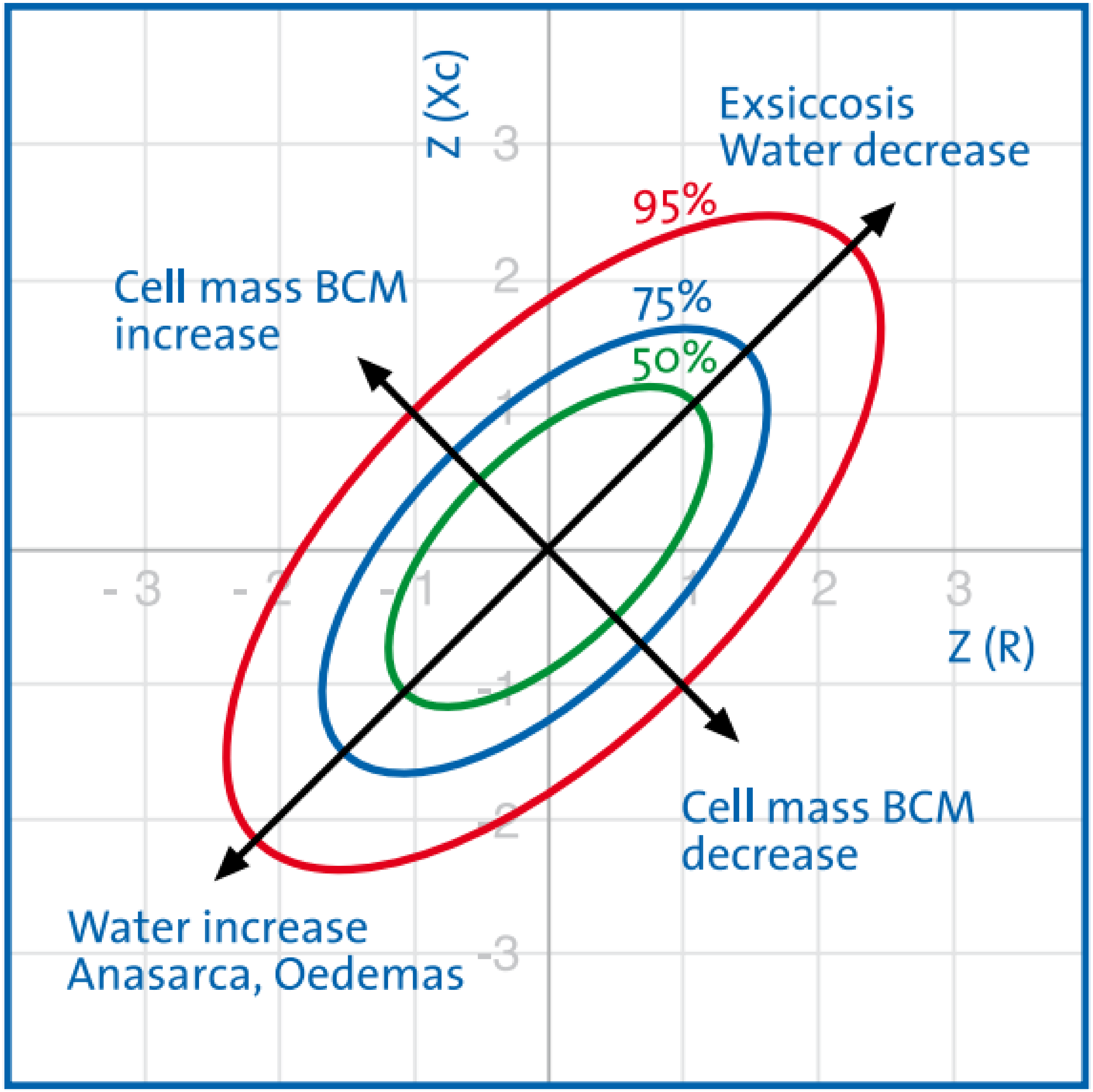
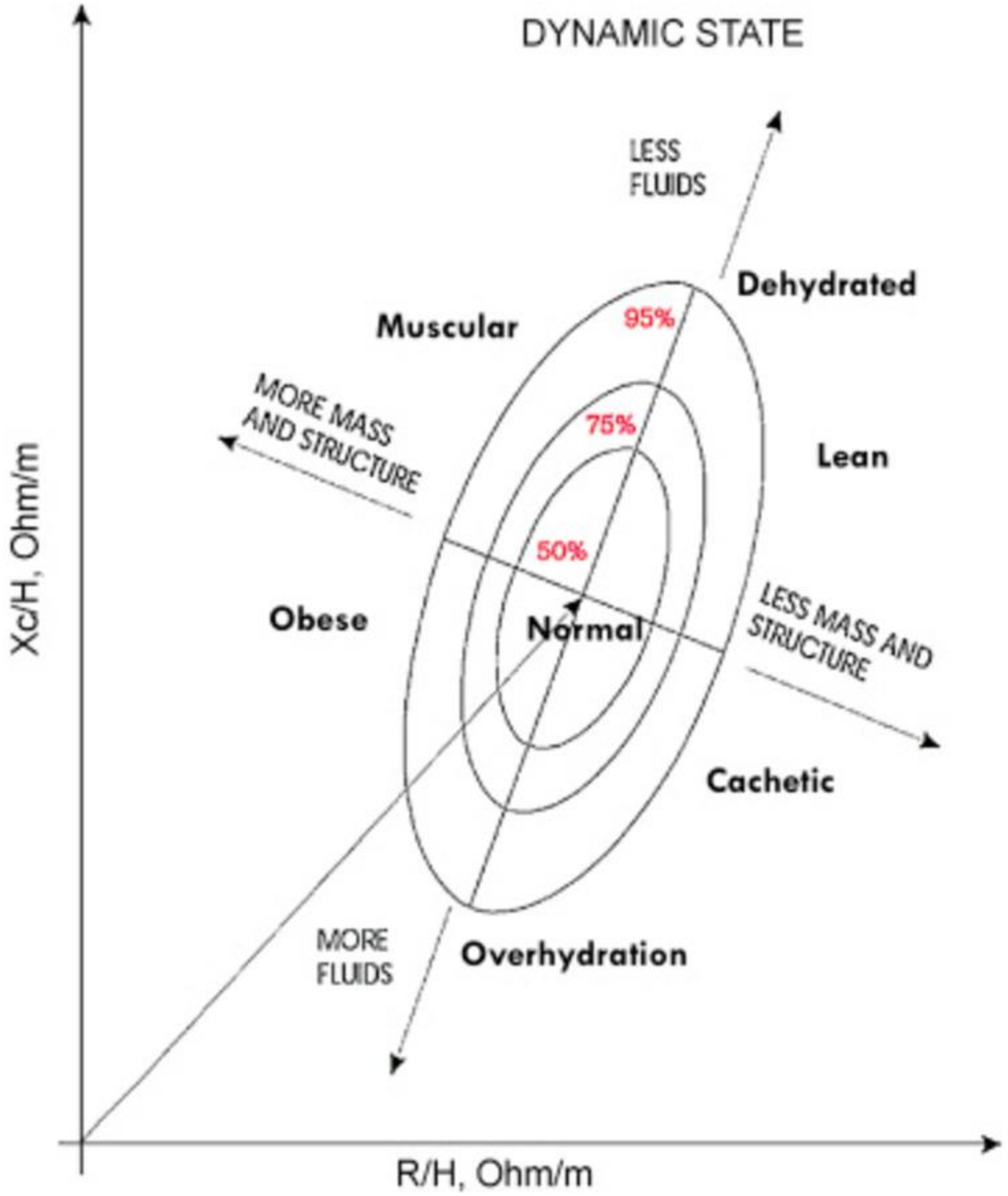
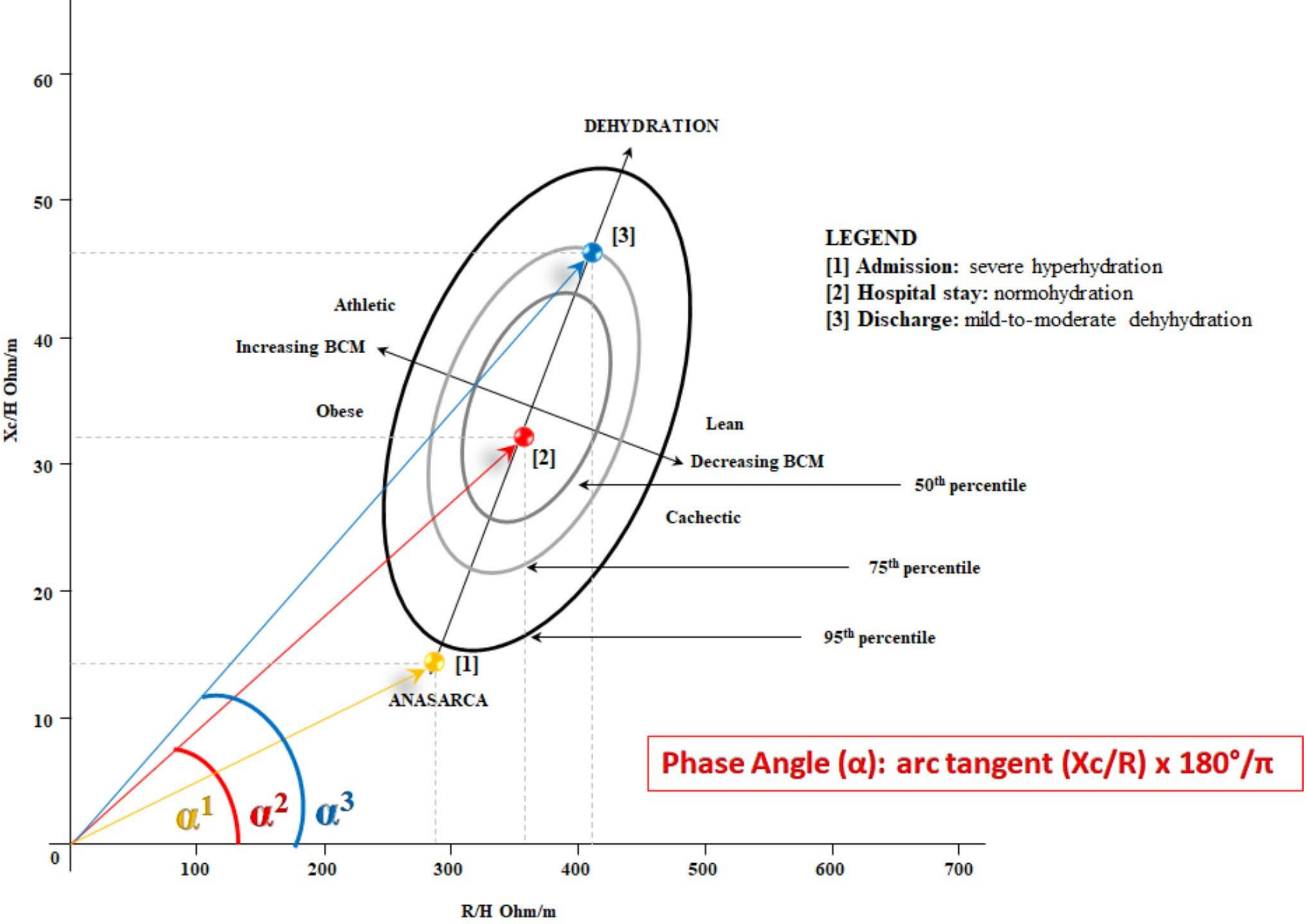
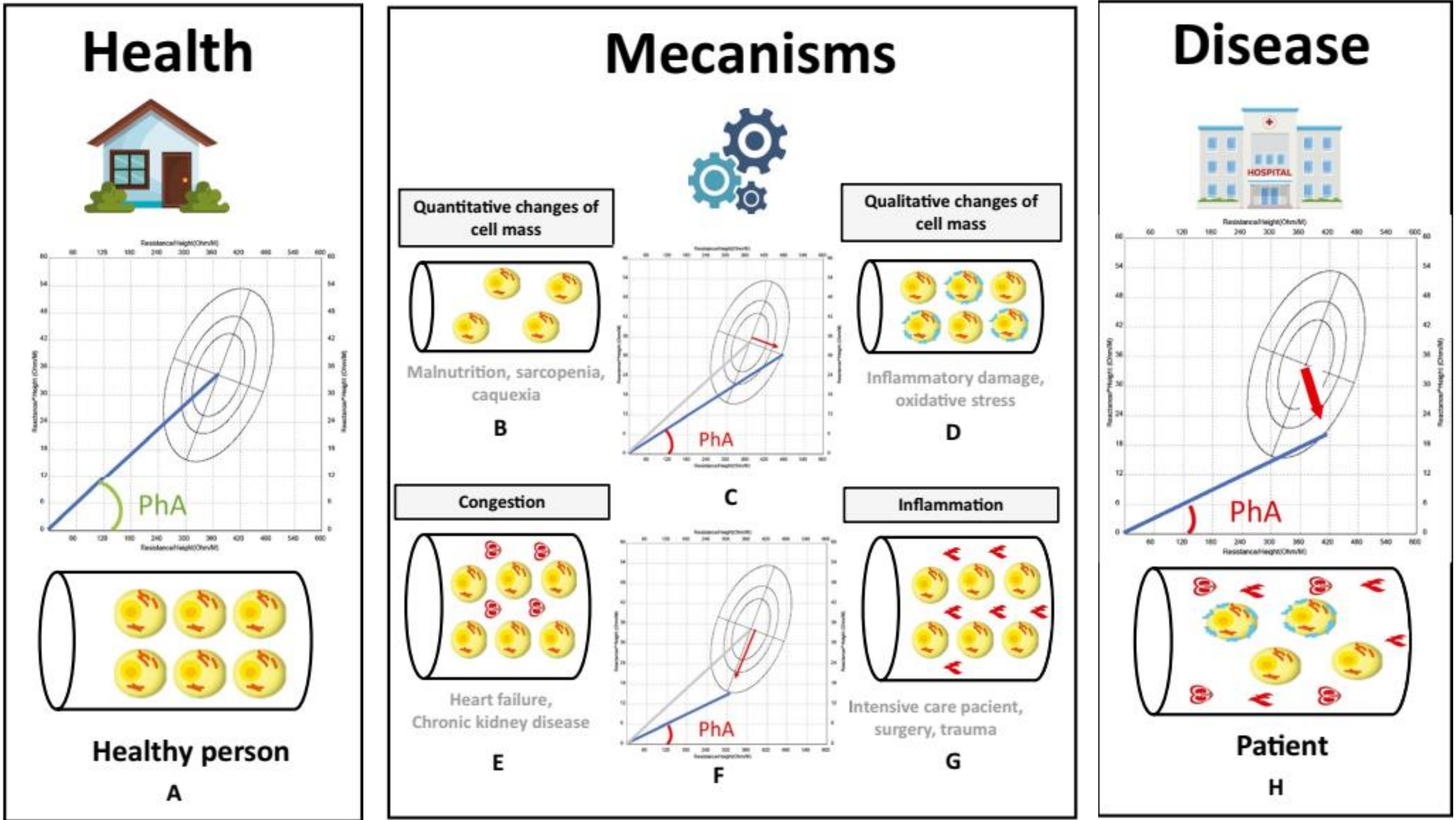


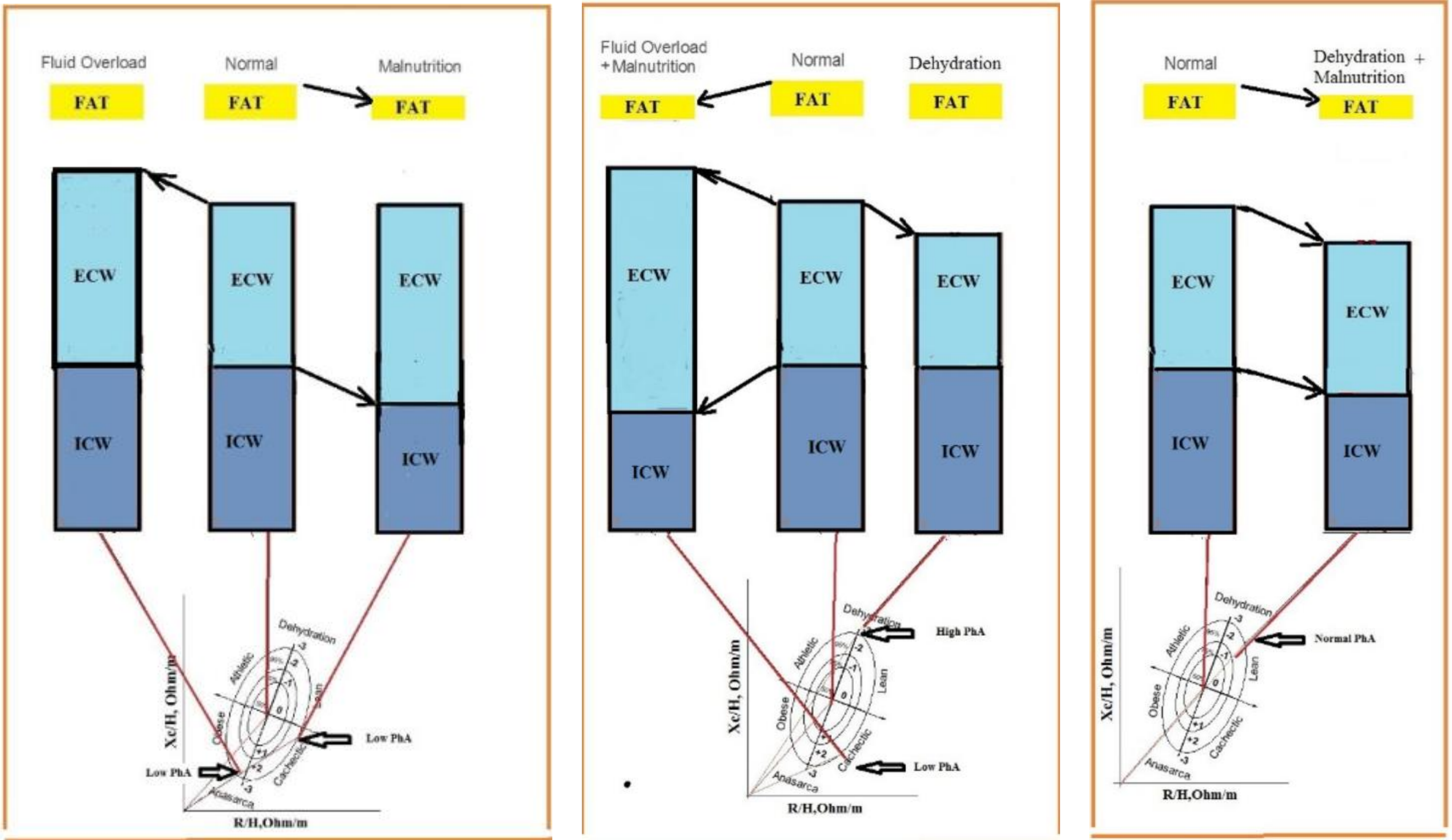
Fig. H.3 Interpretation graphics with vector percentiles




DEHYDRATION
LEGEND
[1] Admission: severe hyperhydration
[2] Hospital stay: normohydration
[3] Discharge: mild-to-moderate dehyhydration
Athletic
Increasing BCM
Obese
Lean
Decreasing BCM
50th percentile
Cachectic
75th percentile
95th percentile
[1]
[2]
[3]
ANASARCA
Phase Angle (α): arc tangent (Xc/R) x 180°/π
α1
α2
α3
Xc/H Ohm/m
R/H Ohm/m
0
10
20
30
40
50
60
100
200
300
400
500
600
700



Health
Mecanisms
Disease
HOSPITAL
Quantitative changes of cell mass
Qualitative changes of cell mass
PhA
Malnutrition, sarcopenia, caquexia
B
Inflammatory damage, oxidative stress
D
C
Congestion
Inflammation
Heart failure, Chronic kidney disease
E
F
Intensive care pacient, surgery, trauma
G
Healthy person
A
Patient
H


Fluid Overload
Normal
Malnutrition
FAT
FAT
FAT
ECW
ECW
ECW
ICW
ICW
ICW
Dehydration
Athletic
Lean
Obese
Cachectic
Anasarca
Low PhA
Low PhA
Xc/H, Ohm/m
R/H,Ohm/m
Fluid Overload
+Malnutrition
Normal
Dehydration
FAT
FAT
FAT
ECW
ECW
ECW
ICW
ICW
ICW
Dehydration
Athletic
Lean
Obese
Cachectic
Anasarca
High PhA
Low PhA
Xc/H, Ohm/m
R/H,Ohm/m
Normal
Dehydration +
Malnutrition
FAT
FAT
ECW
ECW
ICW
ICW
Dehydration
Athletic
Lean
Obese
Cachectic
Anasarca
Normal PhA
Xc/H, Ohm/m
R/H,Ohm/m

[BWA2.0]

ID	Height	Age	Gender	Test Date / Time
0064864499	171cm	50	Male	2024.10.09. 08:34

ECW Ratio Analysis

	Under	Normal	
ECW Ratio	0.320 0.340 0.360	0.380 0.390	0.368

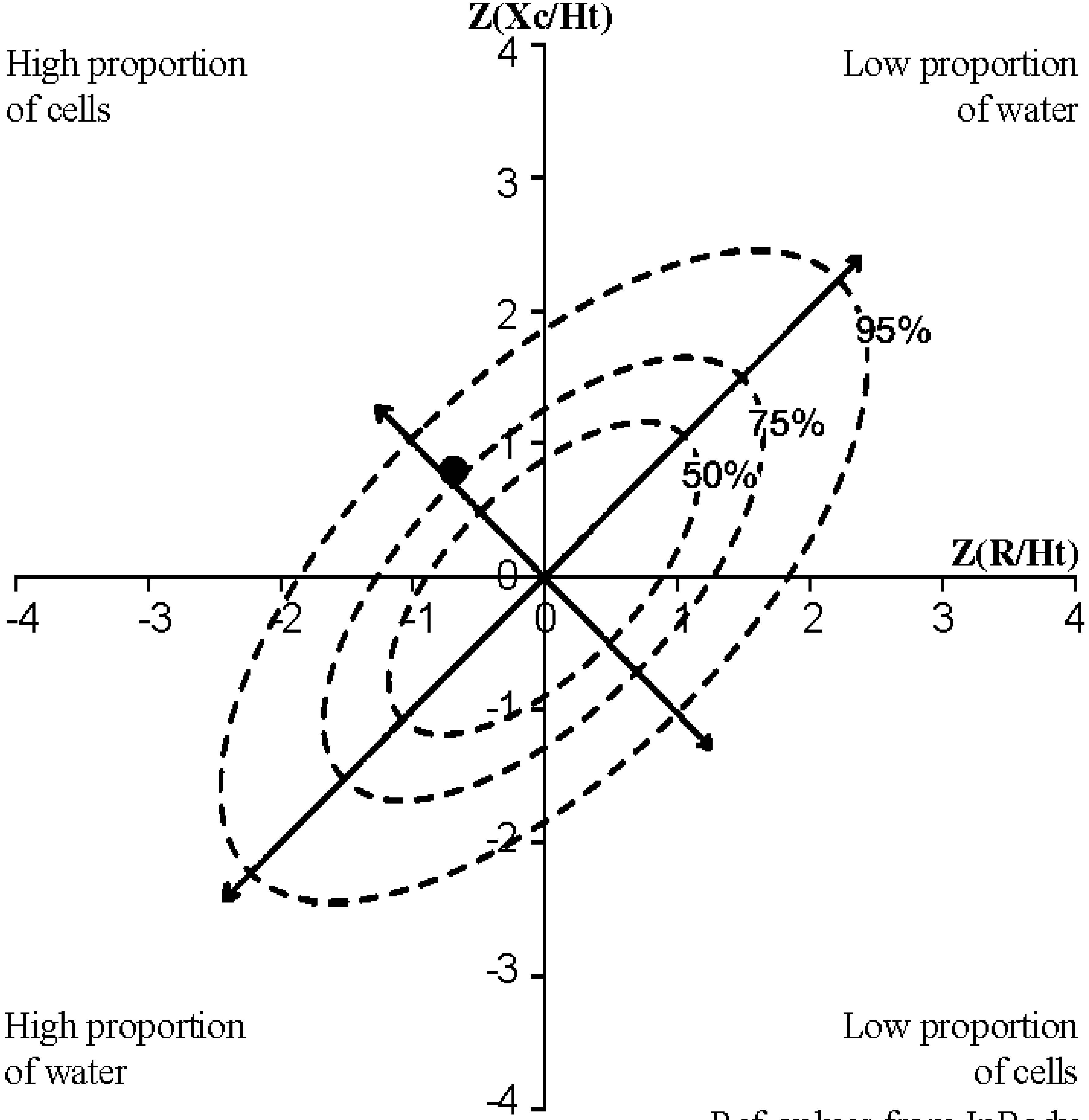
Whole Body Phase Angle

Proximal

ϕ (°) 50 kHz | 9.2 °

Bioeletrical Impedance Vector Analysis

● Current data ◇ Previous data



Ref. values from InBody

BWA Body Water

[BWA2.0]

ID	Height	Age	Gender	Test Date / Time
241009-1	167cm	78	Male	2024.10.09. 14:08

ECW Ratio Analysis

	Under			Normal		Over					
ECW Ratio	0.320	0.340	0.360	0.380	0.390	0.400	0.410	0.420	0.430	0.440	0.450
	0.419										

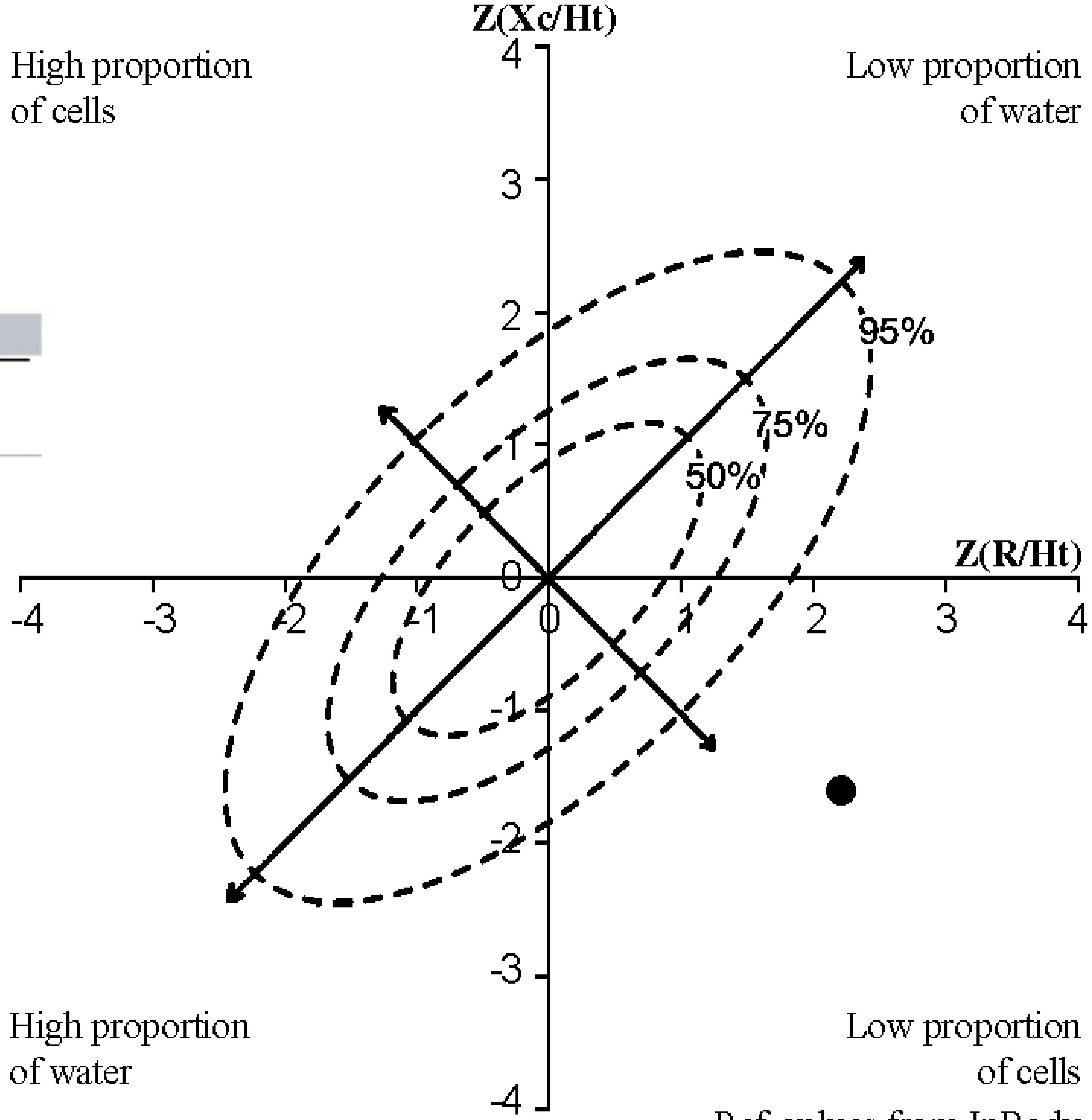
Whole Body Phase Angle

Proximal

ϕ (°) 50 kHz | 3.8 °

Bioeletrical Impedance Vector Analysis

● Current data ◇ Previous data



Ref. values from InBody

BWA

[BWA2.0]

ID	Height	Age	Gender	Test Date / Time
241009-2	180cm	53	Male	2024.10.09. 14:28

ECW Ratio Analysis

	Under			Normal		Over			
ECW Ratio	0.320	0.340	0.360	0.380	0.390	0.400	0.410	0.420	0.430
								0.421	

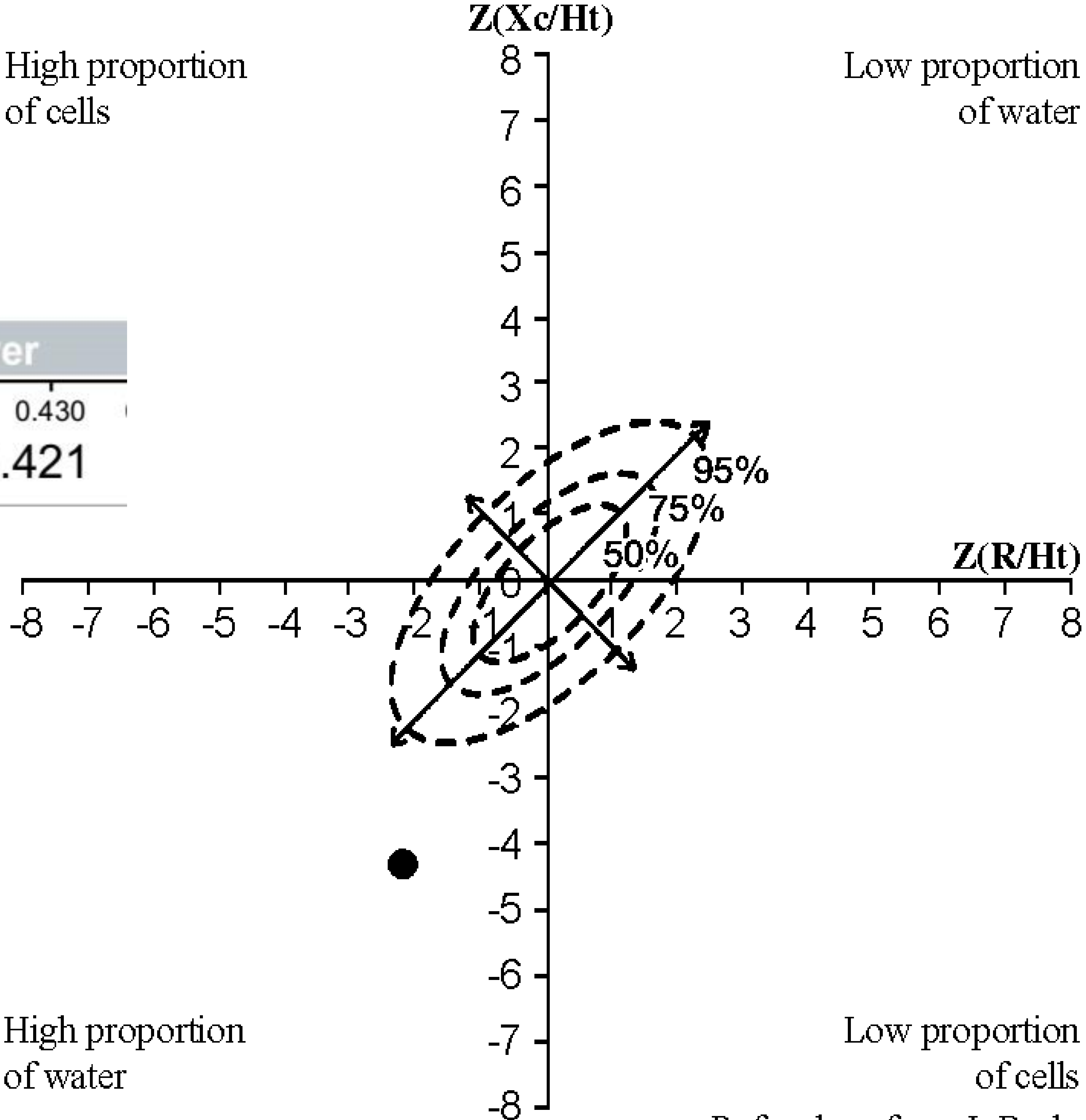
Whole Body Phase Angle

Proximal

ϕ(°) 50 kHz | 4.4 °

Bioeletrical Impedance Vector Analysis

● Current data ◇ Previous data



Ref. values from InBody

InBody Body Water

[InBodyS10]

ID	Height	Age	Gender	Test Date / Time
4321930189	162cm	72	Male	14.08.2024. 17:56

Body Composition History

	07.12.23. 18:54	12.12.23. 18:55	19.12.23. 00:46	23.01.24. 22:40	23.01.24. 23:06	06.02.24. 21:54	04.03.24. 00:14	14.08.24. 17:56
Weight (kg)	80.2	77.0	72.4	71.2	71.0	70.0	71.2	68.6
SMM (kg) Skeletal Muscle Mass	37.9	37.1	33.5	31.4	32.4	32.5	33.4	30.4
PBF (%) Percent Body Fat	11.7	10.3	14.1	18.7	16.4	16.1	15.5	20.0
ECW Ratio	0.430	0.423	0.418	0.406	0.405	0.391	0.389	0.391

Body Water Composition History

	07.12.23. 18:54	12.12.23. 18:55	19.12.23. 00:46	23.01.24. 22:40	23.01.24. 23:06	06.02.24. 21:54	04.03.24. 00:14	14.08.24. 17:56
Weight (kg)	80.2	77.0	72.4	71.2	71.0	70.0	71.2	68.6
TBW (L) Total Body Water	53.7	52.0	46.8	43.2	44.3	43.5	44.3	40.8
ICW (L) Intracellular Water	30.6	30.0	27.2	25.6	26.4	26.5	27.1	24.8
ECW (L) Extracellular Water	23.1	22.0	19.6	17.6	17.9	17.0	17.2	16.0
ECW Ratio	0.430	0.423	0.418	0.406	0.405	0.391	0.389	0.391

☑ Recent ☐ Total