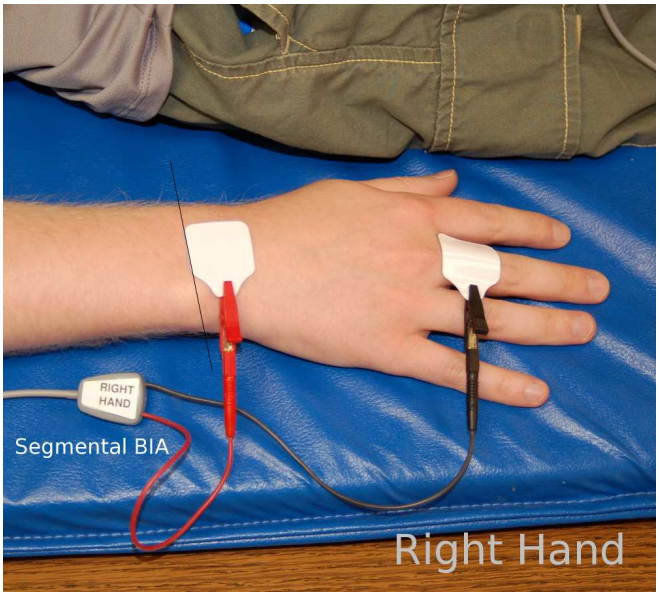
Comparison of more Proximal to Distal electrodes used in BIA

History

In 1983, Dr. Jan Nyboer (deceased April 2000) validated the use of whole body electrical impedance to assess body composition by comparison with hydrostatic weighing in 144 college age male and female subjects [1]. Hydrostatic weight was performed during forced exhalation with residual lung volume estimated as .24 and .28 times measured vital capacity for males and females, respectively. A constant of 0.1 liter was used to estimate gut air. A RJL Systems impedance plethysmograph [6] was used and calibrated to analyze the resistance and reactance of biological conductors up to 1000 ohms. In the total population of males and females, there was a significant correlation between body FAT MASS (r = .86), TBW (r =.947) and LBM (r = .934).

The four electrode techniques presented by Hoffer [2] and adopted by Nyboer incorporated four surface electrodes situated either ipsilaterally or contralaterally on the dorsal surfaces of the hands and feet at the distal metacarpals and metatarsals, respectively, and the distal prominences of the radius and ulnar and between the medial and lateral malleoli at the ankle.

Right foot distal (traditional) electrode placement	Right hand distal (traditional) electrode placement
	

The principle of this protocol was to measure as much of the whole body as possible (arms, legs and torso) where anatomical prominences are easily identified (ankle and wrist bones). This electrode placement technique continues to be used today.

Proximal electrode placement

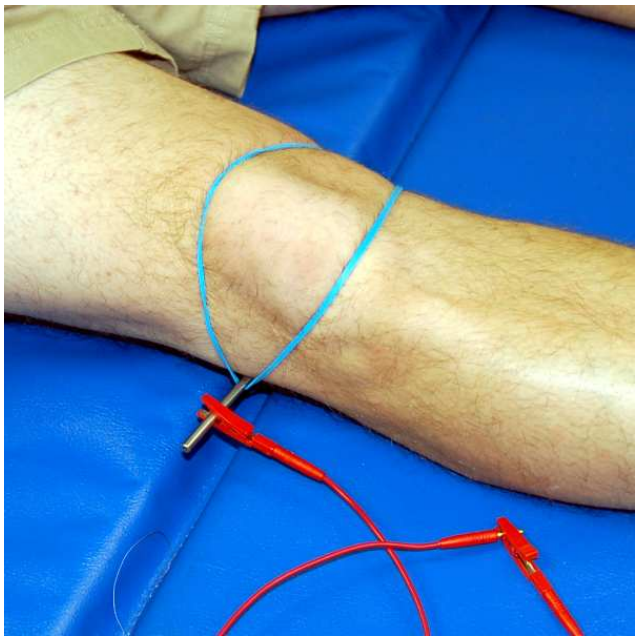
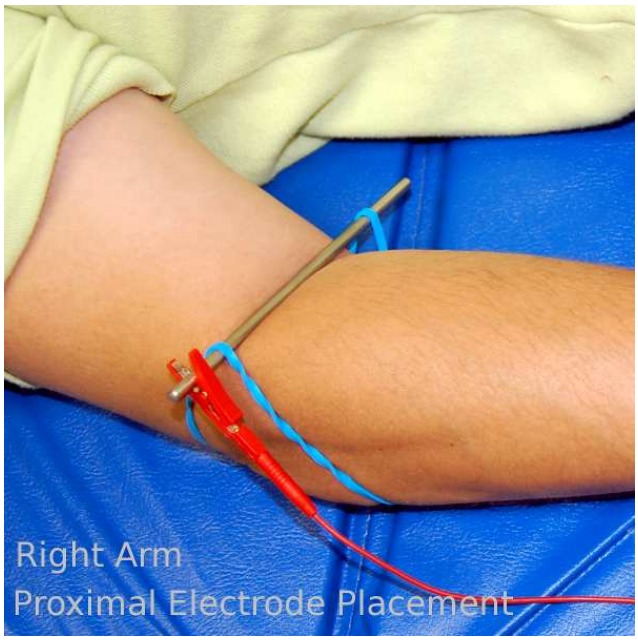
The problem with the historical (distal) electrode placement protocol is that the distal arm and leg (forearm and lower leg) are included in the impedance measurement. These segments contribute greatly to the total impedance value yet represent only a small portion of the overall body composition[3]. By omitting the forearm and lower leg from the impedance measurement, a more proximal electrode placement would reduce the standard error of estimate (SEE) for assessing FAT, LBM and TBW, as shown by Lukaski[4] and Scheltinga[3].

The proximal electrodes consist of stainless steel rods placed at the antecubital and the popliteal fossae. Anatomically, the rods are a very stable and repeatable electrode protocol because of the natural contour of the fossae.

By using a proximal electrode placement instead of a distal one, Lukaski reported a 33.2 percent reduction in SEE *(SEE difference/mean SEE X 100)* when predicting FFM from bioelectrical impedance in a population of 80 healthy volunteers. The mean resistance value was 209 ± 4 ohms and 24 ± 1 ohm reactance using proximal electrodes. The traditional, more distal, electrode placement resulted in 510 ± 8 ohms resistance and 58 ± 1 ohms reactance. The Lukaski data illustrates that the distal segments of the arm and leg contribute more than 50 percent to the resistance and reactance measurements.[4] The combination of using DEXA as a criterion method to evaluate FFM and stepwise multiple regression analysis to predict FFM from proximal and distal electrode placement resulted in a marked improvement in R^2 and SEE.

Protocol	R^2	SEE Kg	Equations - Henry C. Lukaski - M=1 F=0
Distal	0.970	2.11	$FFM = 0.473 \cdot \frac{Ht^2}{R_{distal}} + 0.265 \cdot Wt + 4.985 \cdot Sex + 3.54$
Proximal	0.985	1.50	$FFM = 0.183 \cdot \frac{Ht^2}{R_{proximal}} + 0.296 \cdot Wt + 1.89 \cdot Sex + 3.82$

The 0.6 Kg SEE difference between these two methods is highly significant in understanding the importance of more proximal electrodes. It is also interesting to note that, not only did the use of proximal electrodes improve the correlation and reduce the standard error of estimate, the resulting model places a much smaller significance on the gender of subject.

Right leg proximal electrode placement	Right arm proximal electrode placement
	

The investigational proximal electrode kit from RJL

Type 316 stainless was chosen for our proximal electrodes because of its high biocompatibility.[5] Instead of using velcro to hold the rods in place, as Lukaski did, RJL Systems chose latex free rubber bands (Alliance, size 117B antimicrobial). These hold the rods in place securely and eliminate sanitary concerns by being disposable.

The RJL Systems proximal electrode kit contains the following:

- Two 6-inch 316 type stainless steel rods (3/16 inch dia) for the arm (one is a spare).
- Two 8-inch 316 type stainless steel rods (3/16 inch dia) for the leg (one is a spare).
- 1 box (100 count) latex free (blue) rubber bands to hold the rods placed in the fossae of the arm and leg.
- 1 Stay Fresh pack (100 count - 50 tests) source "stick on" electrodes.
- 1 box (100 count) alcohol swabs to clean the stainless steel rods after each use.
- Carrying case where the above items are easily accessible.
- Price $100.00, free with the purchase of a Quantum IV.
- Please note: RJL Systems does not provide any software or prediction equations for proximal electrodes. There are FFM equations in the Lukaski paper referenced below.

Smaller (shorter) stainless steel electrodes are available for infants and babies upon request at no additional cost.

References and Footnotes:

1 Nyboer, J., Liedtke, R.J., Reid, K.A. and Gessert, W.A.: Nontraumatic electrical detection of total body water and density in man. Proceedings of VIth ICEBI, 381-384, 1983.

2 Hoffer, E.C., Meador, C.K. and Simpson, D.C.: A relationship between whole body impedance and total body water volume. Annals N.Y. Acad. of Sciences, 197: 452-469, 1970.

3 Marc R. Sscheltinga, M.D., Dannyo.Jacobs, M.D., Thomas D. Kimbrough, M.D., and Douglas W. Wilmore, M.D.: Alterations in Body Fluid Content Can Be Detected by Bioelectrical Impedance Analysis. Journal of Surgical Research 50,461-468 (1991)

4 Henry C. Lukaski: Comparison of Proximal and Distal Placements of Electrodes to Assess Human Body Composition by Bioelectrical Impedance. Human Body Composition, Edited by K.J. Ellis and J.D. Eastman, Plenum Press, New York, 1993

5 Haudrechy, P., Foussereau, J., Mantout, B., Baroux, B.: Nickel release from 304 and 316 stainless steels in synthetic sweat. Comparison with nickel and nickel-plated metals. Consequences on allergic contact dermatitis. Corrosion Science, Volume 35, Issues 1-4, 1993, Pages 329-336

6 The RJL Systems BIA analyzer delivered a 50 Khz constant current between the outer two electrodes. The voltage drop between the inner two is measured with a high input impedance amplifier. **The impedance of the skin and electrode polarization does not effect the measurement of total body impedance with the four surface electrode technique since negligible current is drawn through the skin by the isolated voltage detector**. The four surface electrode technique utilizing a constant deep homogeneous electrical field in the variable conductor of the human body also minimizes problems with field distribution and electrode irregularities. (1982)