Evaluation of gastric emptying in critical ill patients using Electrical Impedance Method (EIM)

Dr. Ariful Basher

Introduction:

- Gastrointestinal dysfunction is a common problem observed in the intensive care unit (ICU) worldwide
- Gut problems in ICU may often be fairly occult. Gut is the first site of ischemia due to shock.
- Feeding intolerance, and leads to malnutrition and worse clinical outcomes
- Gastric motility is one of the most critical physiological functions of the human body.
- Coordinated gastric motility is necessary for digestion and the absorption of dietary nutrients

Introduction, Contd__

- The most accurate clinical methods for evaluation of gastric motility are radio nucleotide techniques, but it cannot be done continuously and has associated radiation hazards.
- An electrical bio impedance technique is a method used to extract physiological and pathological information from the human body according to the electrical property of the tissue and organs.
- Electrical impedance essentially means obstruction to electrical current. Typical ions containing liquid offers less obstruction (low impedance), so presence of liquid in stomach will give low impedance. After feeding we expect a quick fall in impedance followed by a gradual increase in impedance during gastric emptying, indirectly related to volume remaining in stomach.
- A low amplitude alternating current is injected across a pair of electrodes while the voltage difference produced on another pair of electrodes is measured.

Introduction, Contd__

The present work was taken up to investigate the possibility of applying EIM in the non-invasive monitoring of changes in the volume of gastric contents in ICU patients, which if successful, is expected to allow a better decision to be made, whether feeding should be stopped or resumed to a patient in an ICU.

OBJECTIVES OF THE STUDY

General Objective:

To evaluate the use of Electrical Impedance(EI) for non-invasive monitoring of gastric emptying inmechanically ventilated patients admitted in an Intensive Care Unit (ICU).

Specific Objectives:

To determine the effect of nasogastric feeding on the electrical impedance levels

To estimate the gastric emptying time by measuring the changes in the electrical impedance levels.

To measure the gastric residual volume of the nasogastric feed and relates it with the electrical impedance levels.

To determine the sensitivity and specificity of the impedance method in assessing gastric emptying.

Literature Review

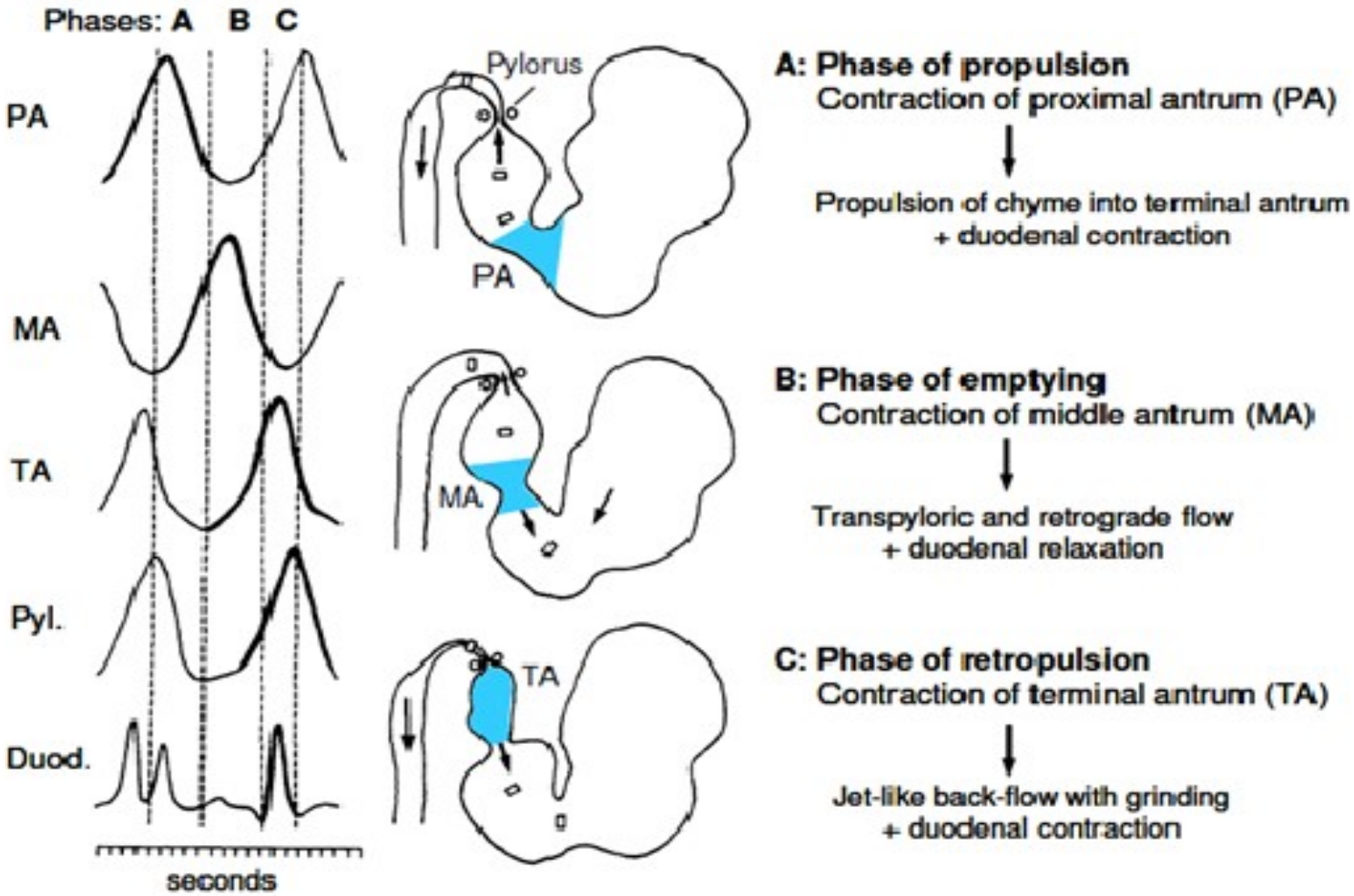


Fig. 2.2 Different phases of antral contraction.

Sampling technique: Purposive sampling

Inclusion criteria:

- All mechanically ventilated patient in Intensive Care Unit (ICU) who had nasogastric tube feeding
- Patient aging more than 12 years
- Patient relatives gave informed written consent.

Exclusion criteria:

- Patient suffering from uncontrolled Diabetes Mellitus
- Patient with known gastric motility disorder.
- Patient in total parenteral nutrition in ICU.

Data collection procedure

- The following data will be collected at study enrolment: age, sex, body mass index, types and amount of feeding, comorbid conditions, sepsis, microbiology results, Simplified Acute Physiology Score II .

- Within 24 hours after ICU admission, the following information will be recorded, if needed, through performing appropriate measurements: heart rate, blood pressure, body temperature, and use of catecholamine. Survival status was assessed by APACHE II score. Patient outcome was also documented. Survival status will be assessed.

- This information will be used to assure the internal validity of the study (homogeneity of the study group).

- Assessment of gastric residual volume by nasogastric suction and electrical impedance device were performed.
- Baseline impedance recording was established before starting NG feeding after overnight fasting.
- Impedance changes was recorded during 150-200 ml of formula feed ingestion at room temperature and continued up to 2 hours before next feeding.
- At this point nasogastric suction was performed to measure gastric residual volume.
- Those patient whom impedance value initially decline during feeding than gradually back to base line with in 120 minutes before next feeding was proposed normal gastric emptying.
- If this patient had no GRV during nasogastric suction then it was considered true positive, but if GRV was found (30ml) than assumed to be false positive.
- If no change observed even after 2 hours considered delayed gastric emptying, and if GRV suction showed significant gastric content (>30ml) was said true negative, if no GRV than believed false negative.

- Electrical impedance measurements, a custom made instrument developed by the Department of Biomedical Physics & Technology of the University of Dhaka, the innovators of Focused Electrical Impedance (FIM)/ Tetrapolar Electrical Impedance Method (TPIM) was used.

- Data were collected with a pre-tested structured questionnaire containing history, clinical examination, laboratory investigations, etc.

- Data were compiled in pre-designed case record forms. Base line characteristic data were analyzed using the windows based SPSS 23.0 and electrical impedance data were analyzed by Excel, 2016 software.

Hardware and Software:

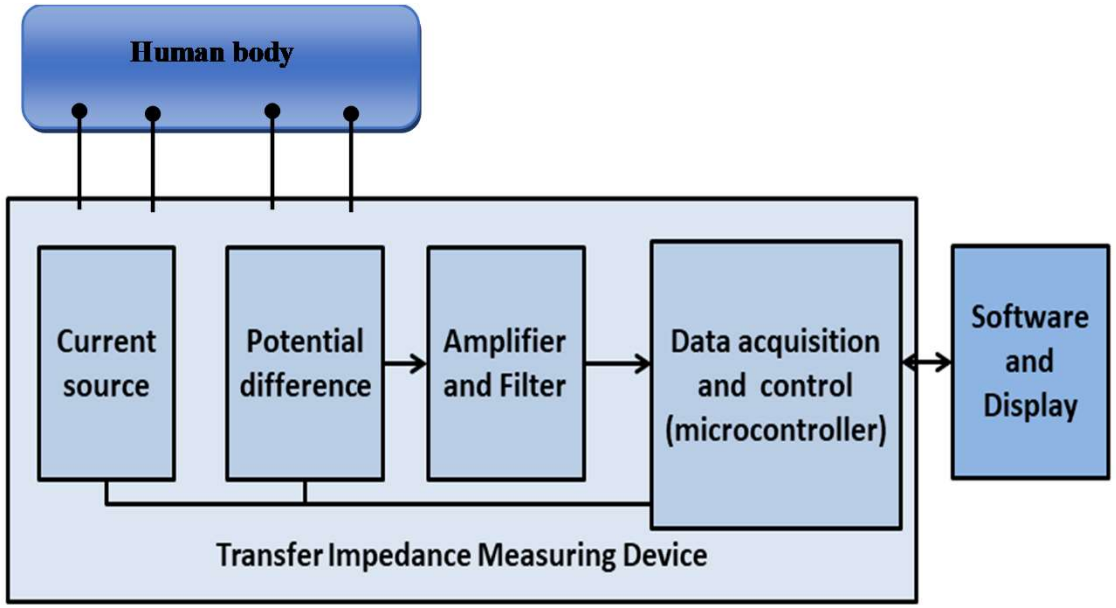


Fig.3.2 Block diagram of the TPIM/FIM device made at Dhaka University

Current Source produces an alternating current of 0.5mA amplitude at 230KHz frequency

The electrodes are placed on the body in order to focus the lower part of stomach.

Electrode Placement:

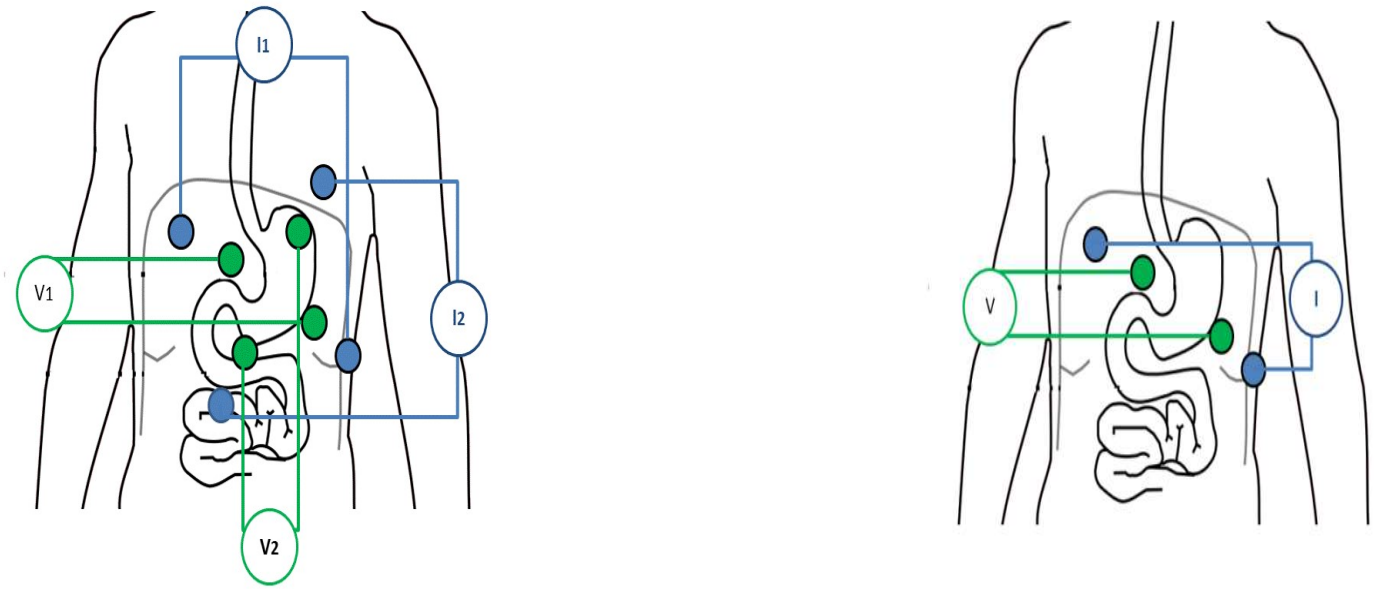
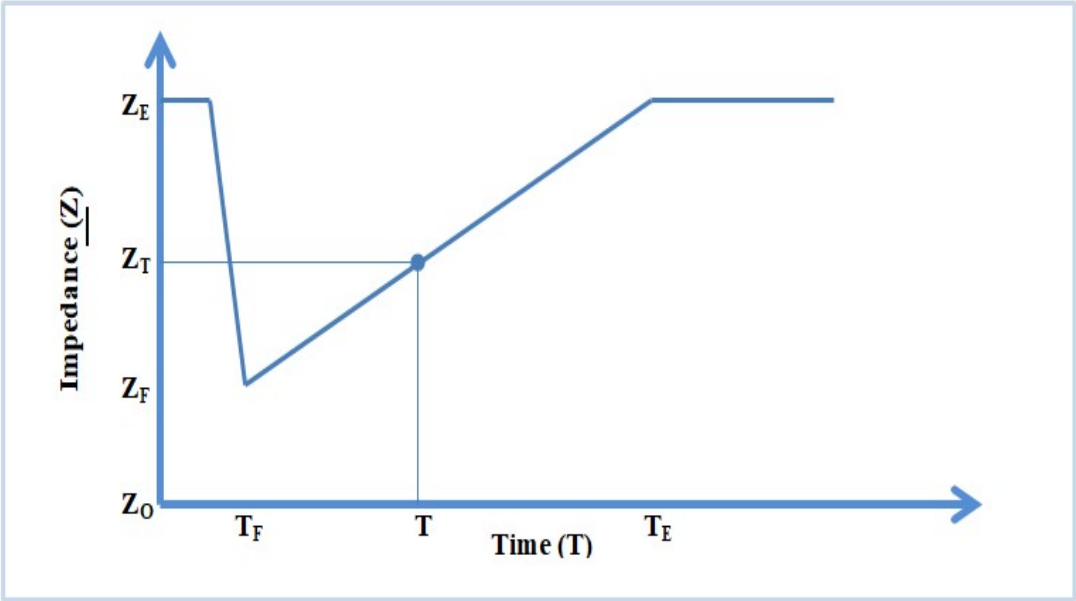


Fig. 3.3 Electrode positions of 8-FIM for gastric emptying measurement

Impedance curve



If I_1 current in set 1create V_1 potential difference in set 1 then Impedance is $Z= V_1/I_1$

If Z_E is the impedance at empty stomach and Z_F is the impedance after feeding V_F ml food then V_F isproportional to $(Z_E–Z_F)$. After T time Z_T is the impedance when remaining food isV_T ml then $(Z_T–Z_F)$ is proportional to digested food volume V_D and $(Z_E–Z_T)$ is proportional to remaining food volume V_R. The relation between food volume in stomach and impedance can be written as,

$$V_R\backslash V_F= (Z_E–Z_T)\backslash(Z_E–Z_F)$$

Or $$V_R = (Z_E–Z_T)\backslash(Z_E–Z_F)xV_F$$

In percentage the remaining food $= V_R\backslash V_F \text{ x}100\% = (Z_E–Z_T)\backslash(Z_E–Z_F)\text{x}100\%$

RESULTS

Completed impedance test data were available from a total of 20 patients.

Table 4.1 Demographic information of study patients

Characteristic	ICU patients (n=20)
Age, years (median (range)	61 (14-90)
Gender (F)	12
BMI (kg/m^2)	22(20-35)
APACHE II score(median(range)	25 (11-43)
Reason for admission	
Clinical Condition	17(85%)
Trauma	2(1%)
Planned surgery	1(0.5%)
Reason for mechanical ventilation	
Cardiac Arrest	4(20%)
Depressed consciousness	7(35%)
Acute respiratory failure	5(25%)
Hemodynamic instability	3(15%)
Planned surgery	1(5%)
Hospital survival	9(45%)
Pre-existing diabetes	9(45%)
Blood glucose concentration(mean(SD)	9.4 (0.5)
Renal replacement therapy	3(15%)
Prokinetics prior to study	2(20%)
Receiving catecholamine	10(50%)
Receiving Fentanyl	12(60%)
Receiving Neuromuscular blocker	2(4%)

APACHE II, Acute Physiology and Chronic Health Evaluation; **BMI,** body mass index'

ICU intensive care unit;

Table 4.2 Clinical parameter and Ventilator setting of study Subjects

Characteristic	ICU patients (n=20)
Glasgow Coma Scale (median (range)	6 (3-14)
Systolic Blood Pressure	109(90-141)
Diastolic BP	62(50-80)
Heart Rate	99 (70-160)
Temp(^{0}F)	99(97-105)
SPO2	98(92-100)
Mode of Ventilation (n,%)	
Control Mood(VCV)	15(75%)
Control Mood(PCV)	2(10%)
SIMV	2(10%)
PSV	1(5%)
FIO2(median (range)	50(40-90)
Set Resp Rate	14(12-16)
Measure RR	19(12-32)
Tidal Volume	480(400-550)
PEEP	5(5-14)
P Max	27.5(14.8—43.7)
P Plateau	12(7-19)
HB (median (range)	9.4(6.5-12)
HcT(median(range)	36(27-42)
WBC	18.000(6000-44000)
Platelet count	1,89000(20000-5,00,000
B Urea	78(46-189)
S creatinine	1.3(0.7-6.3)
S Lactate	2.1(1.2-6.3)
S Calcium	7.8(7.1-8.9)
S Magnesium	2.3(1.4-2.7)
PH	7.4(7.09-7.53)
Pao2	115(60-184)
Pco2	41(29-68)
Hco3	25(16-41)
ETCo2	36(29-41)
S Sodium	141(132-151)
S Potassium	2.7(2.1-4.1)
S Chloride	99((97-108)

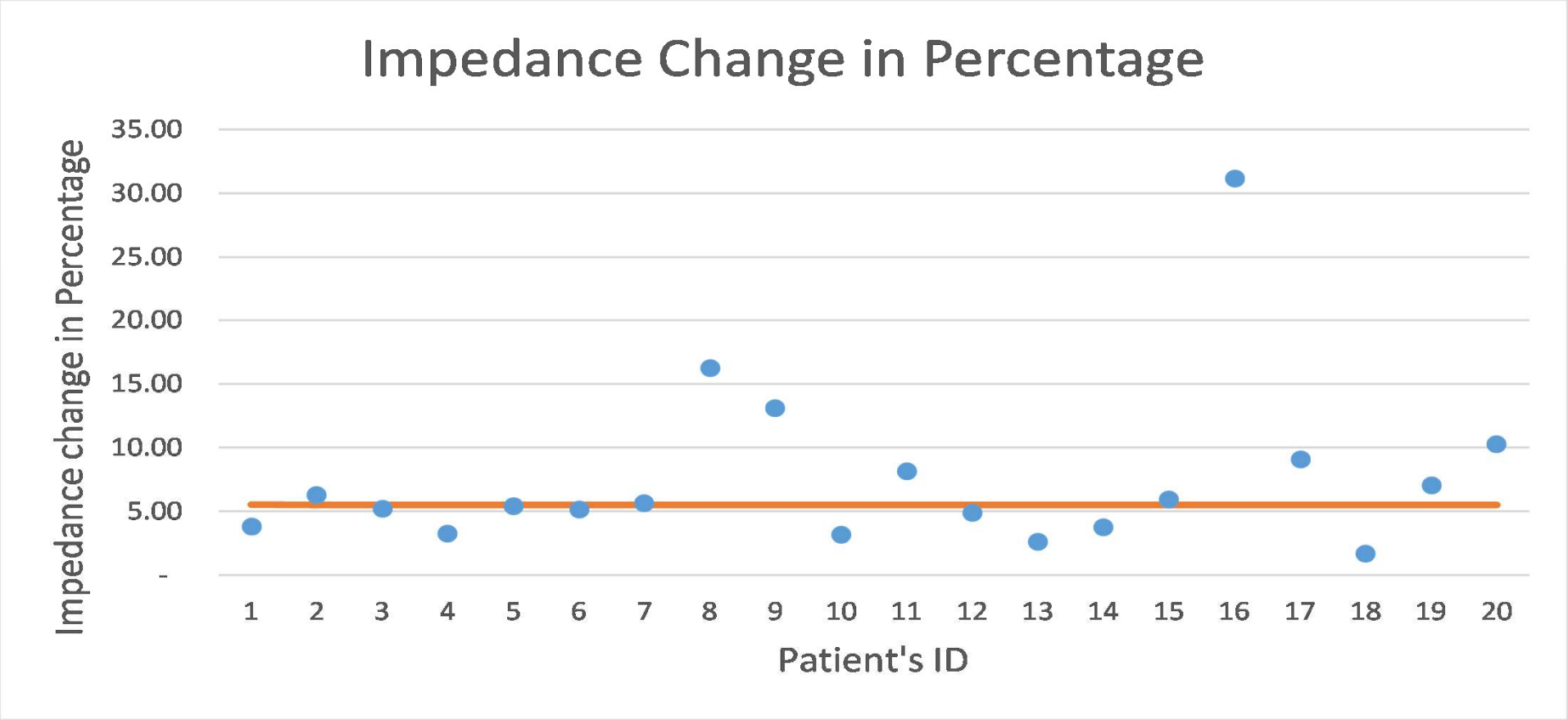
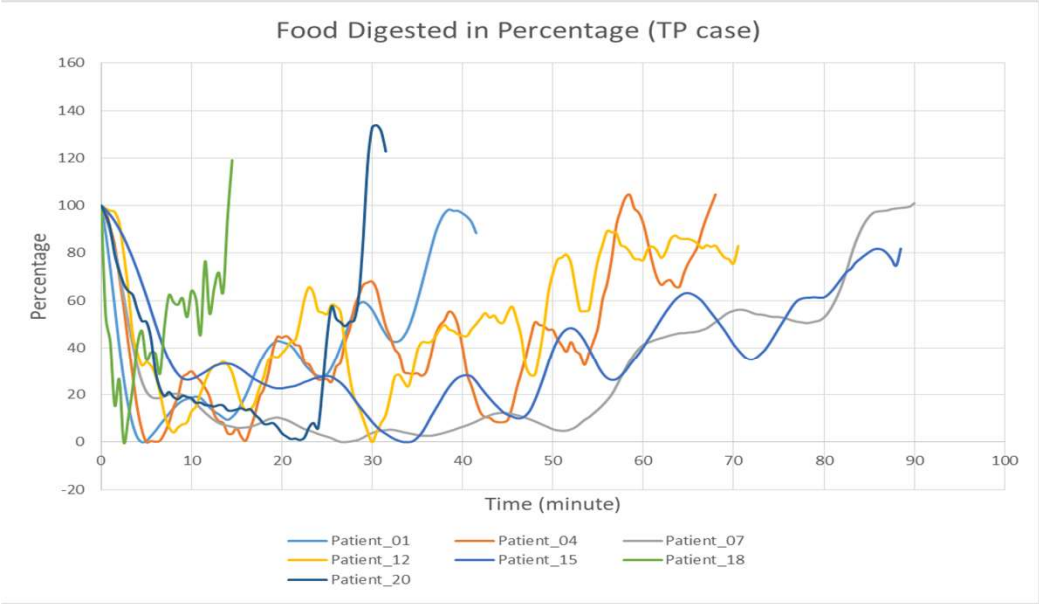


Fig. 4.1 Electrical Impedance changes (%) during feeding in study subject

impedance data obtained before and immediately after introduction of liquid meal were converted to percentage changes and related appropriately to volume of gastric content (%) for each patient. Study showed that median changes in impedance (negative, impedance falls with meal in stomach) were about 5.52% during naso-gastric feeding of 150-200ml formula liquid meal



In some of these patients the final value even went beyond the initial value, which may be due to various reasons, not identified yet and have been ignored.

Fig. 4.2 Percentage of Impedance changes among true positive (TP) cases that correspond to gastric Residual Volume (GRV) by nasogastric suction.

Data from the above seven patient was considered as True Positive (TP).

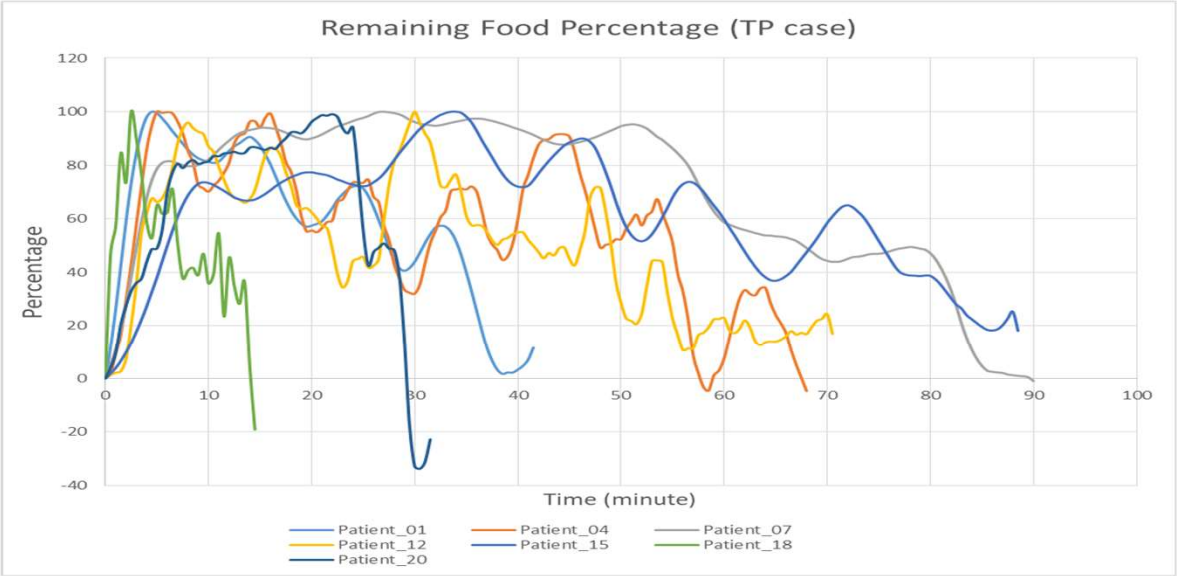


Fig. 4.3 Measured gastric volume over time through electrical impedance(EI) method over time

Average time required for dropping of impedance data to the minimum value was 5 minutes at feeding. During the subsequent emptying phase, the average stomach content emptying time to reach 80% of the initial value is about 51.25 minutes

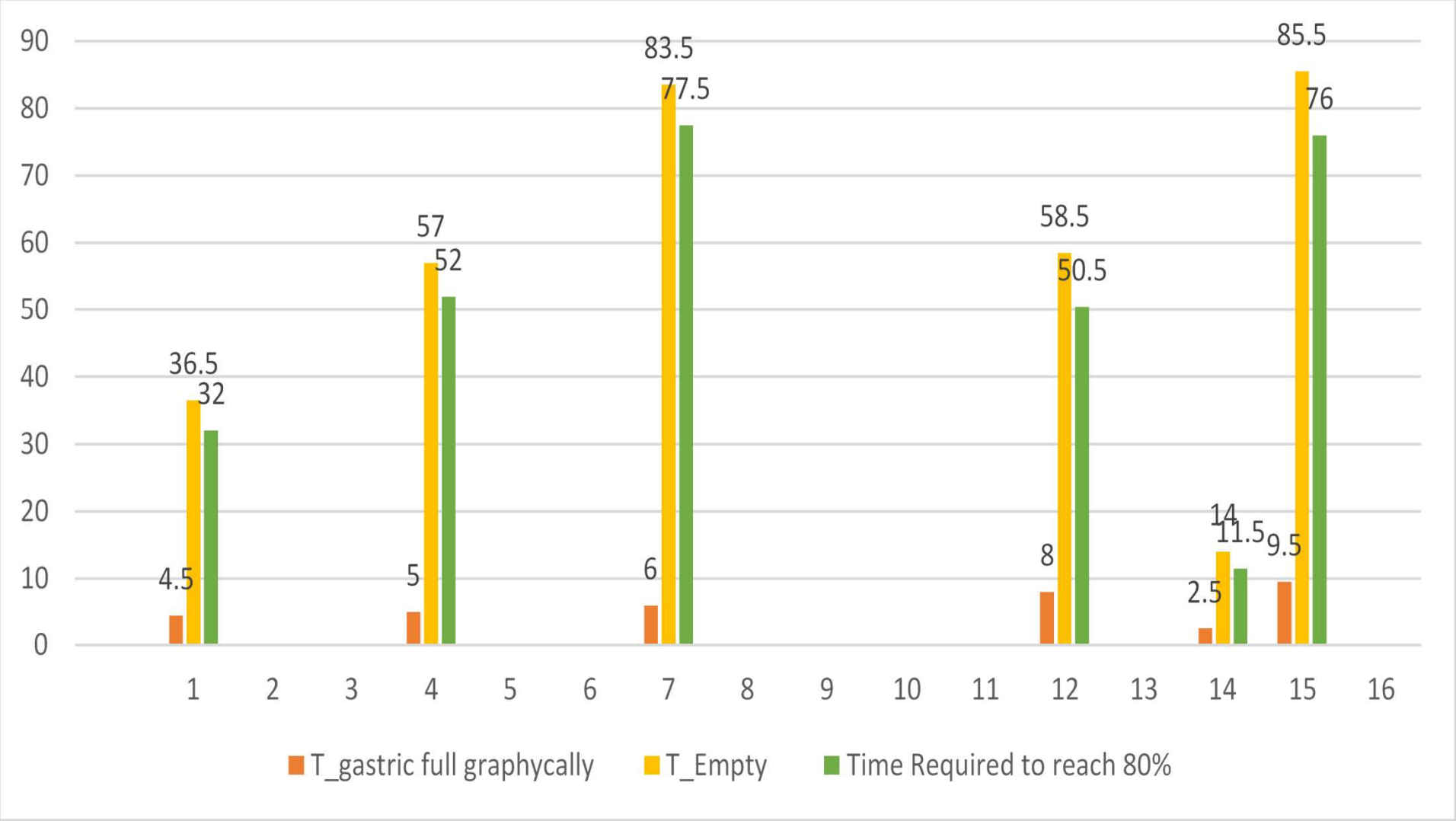


Fig. 4.4 Food absorption time in seven true positive cases.

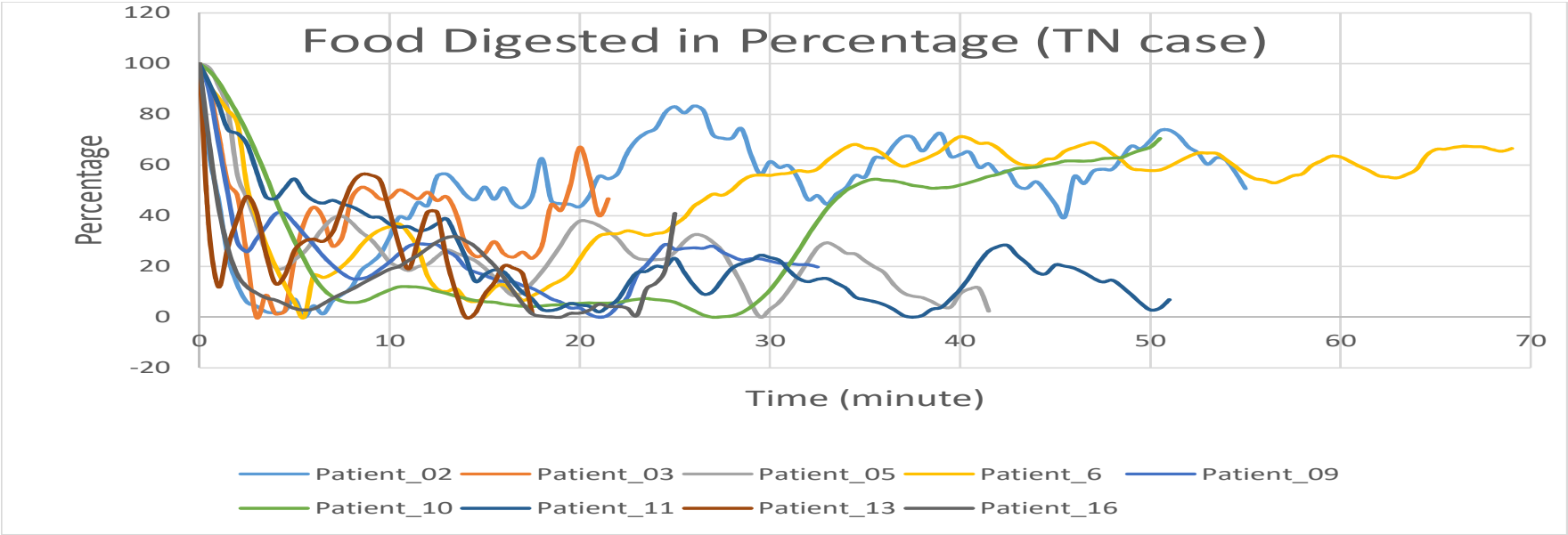


Fig. 4.5 Percentage of Impedance changes among true negative (TN) cases that correspond to gastric Residual Volume (GRV)

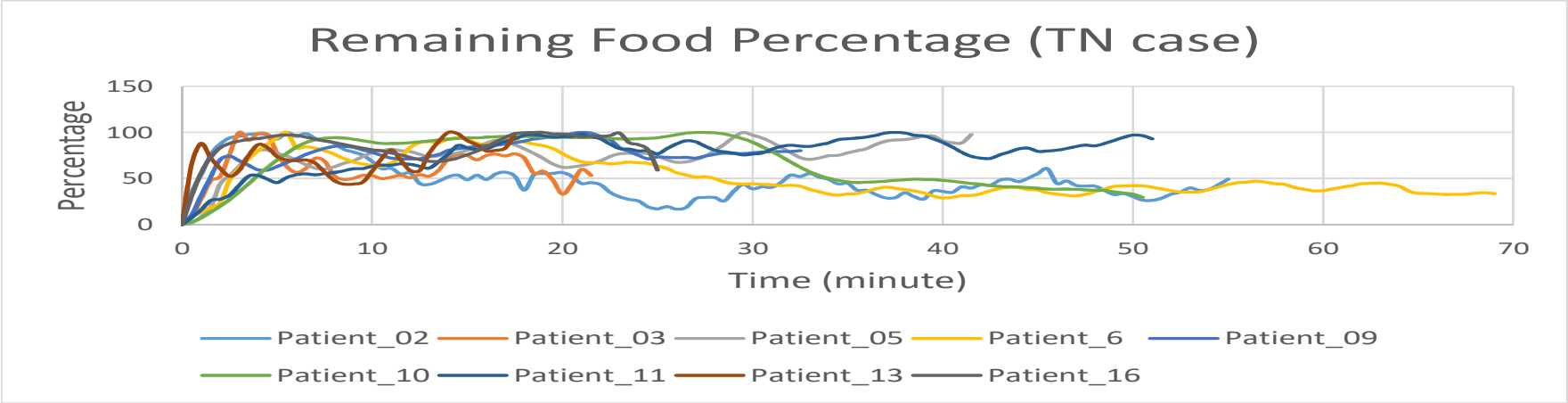


Fig. 4.6 Measured gastric volume over time through electrical impedance (EI) method over time among true negative cases.

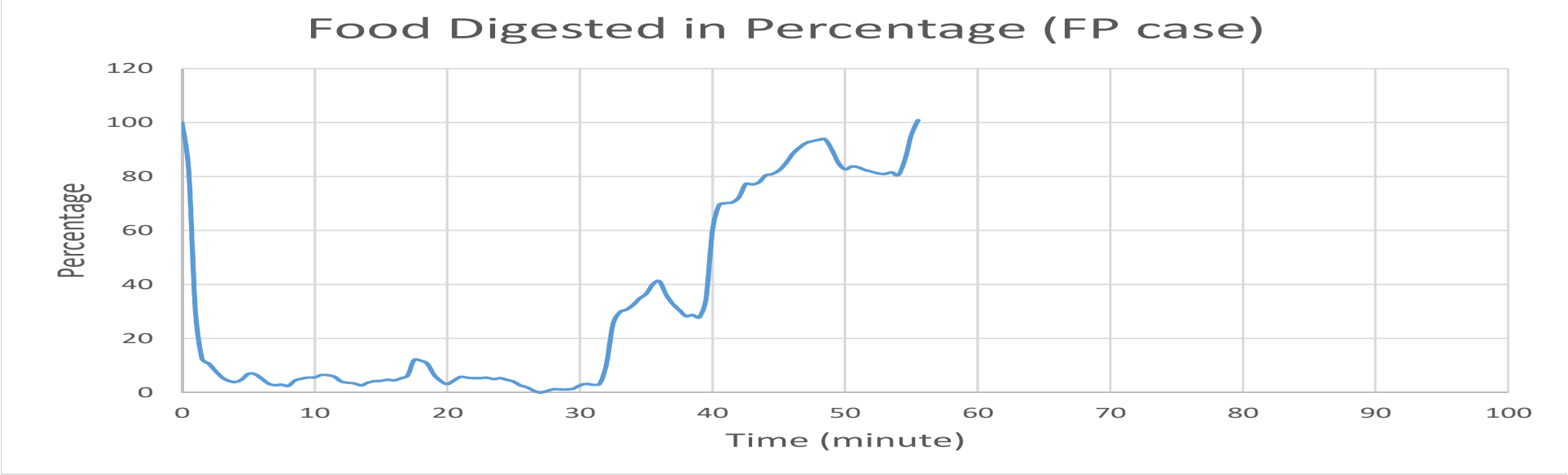


Fig. 4.7 Percentage of Impedance changes among false positive (FP) cases that not correspond to gastric Residual Volume (GRV)

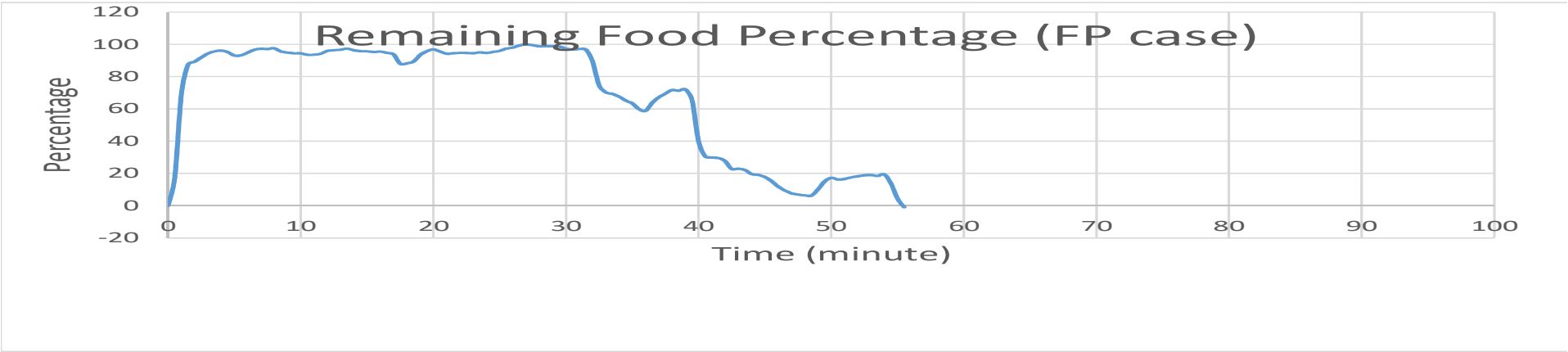


Fig. 4.8 Measurement of gastric volume over time that not correspond to gastric residual volume

It may be seen that for about 30 minutes after feeding the value did not change. Therefore, it is likely that some other factors corrupted the measurement and this is considered as a False Positive (FP) case.

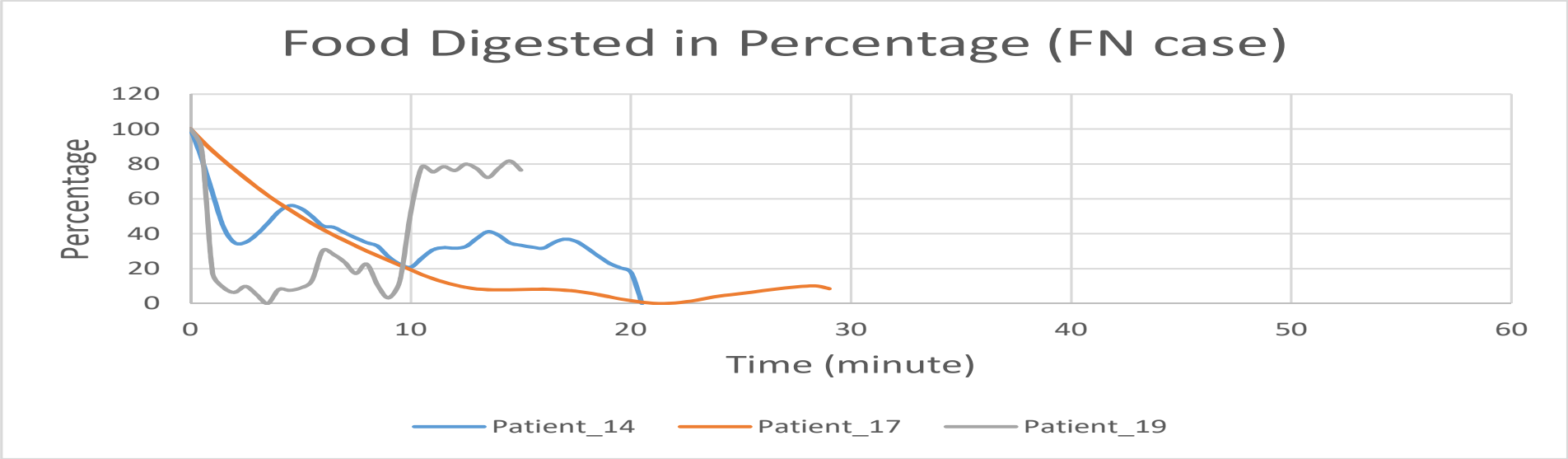


Fig. 4.9 Percentage of Impedance changes among false negative (FN) cases that not correspond to gastric Residual Volume (GRV)

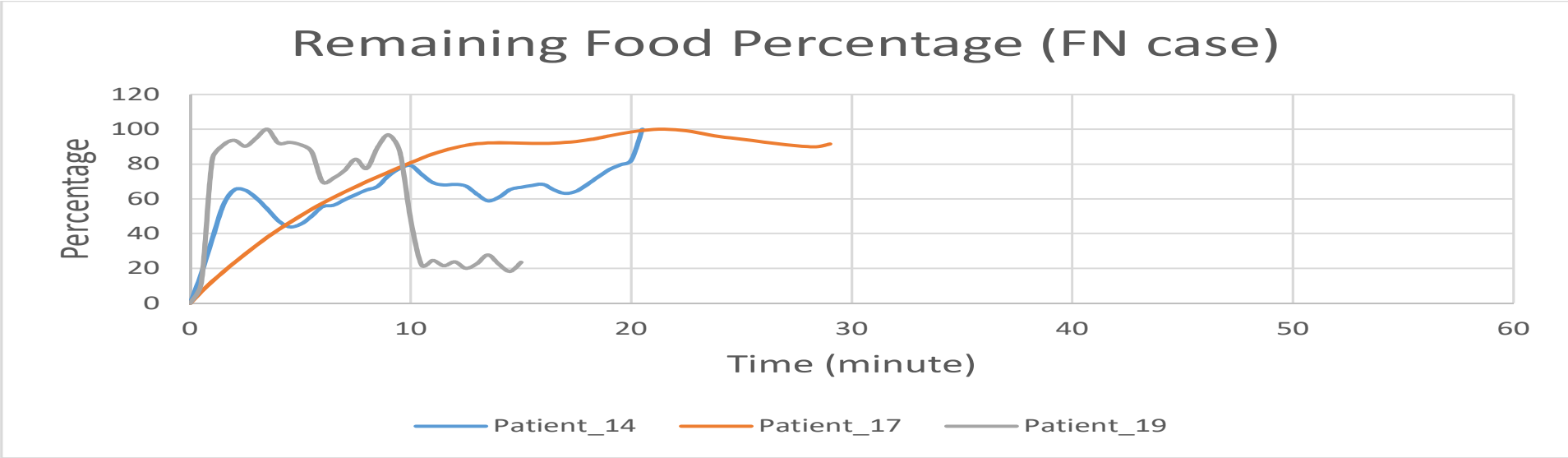


Fig. 4.10, Measurement of gastric volume over time that not correspond to gastric residual volume.

Table 4.3 Sensitivity and specificity of EI for gastric emptying and delayed gastric emptying of the patient.

True Positive(TP)(%)	7(35%)	**Positive Predictive Value(PPV)(%)**	0.875(87.5)
True Negative(TN)(%)	9(45%)	**Negative Predictive Value(NPV)(%)**	0.75(75)
False Positive(FP)(%)	1(5%)	**Sensitivity(%)**	0.7(70)
False Negative(FN)(%)	3(15%)	**Specificity(%)**	0.9(90)
Total	20	**Efficacy(%)**	0.8(80)

Table 4.4 Characteristics of patients who had normal or no gastric emptying on Gastric impedance test.

	Normal gastric emptying (n = 7)	Delayed/No gastric emptying (n = 9)
APACHE II score	25.33±9.87	26.78±9.16
Age (years)	41.8 ± 16.16	56.1±25.02[a]
MeanArterial pressure(MAP) (mmHg)	110±15.02	107±9.53 [a]
Heart rate	99.83±15.14	108.44±25.74
Respiratory rate	21.22±5.6	22.33±3.1
GCS	6.83±4.53	7.46±2.65
Temp ^{0}C	37.5±1.04	38±1.25[a]
HCT	9.83±3.25	8.78±2.10[a]
White cell count (× 109/l)	16.33±5.73	20.77±10.28
Serum creatinine (mmol/l)	1.55±1.16	2.48±1.77 [b]
Serum Sodium	137±1.22	138±1.02
Serum Potassium	4.0±0.62	3.96±0.85
PH	7.36±0.11	7.37±0.4
Fraction of inspired oxygen(FiO_2)	55±8.3	60±14.14[a]

a) $P < 0.05$, versus normal gastric emptying.

b) $P < 0.01$, versus normal gastric emptying.

c) APACHE II, Acute Physiology and Chronic Health Evaluation II; ICU, intensive care unit;

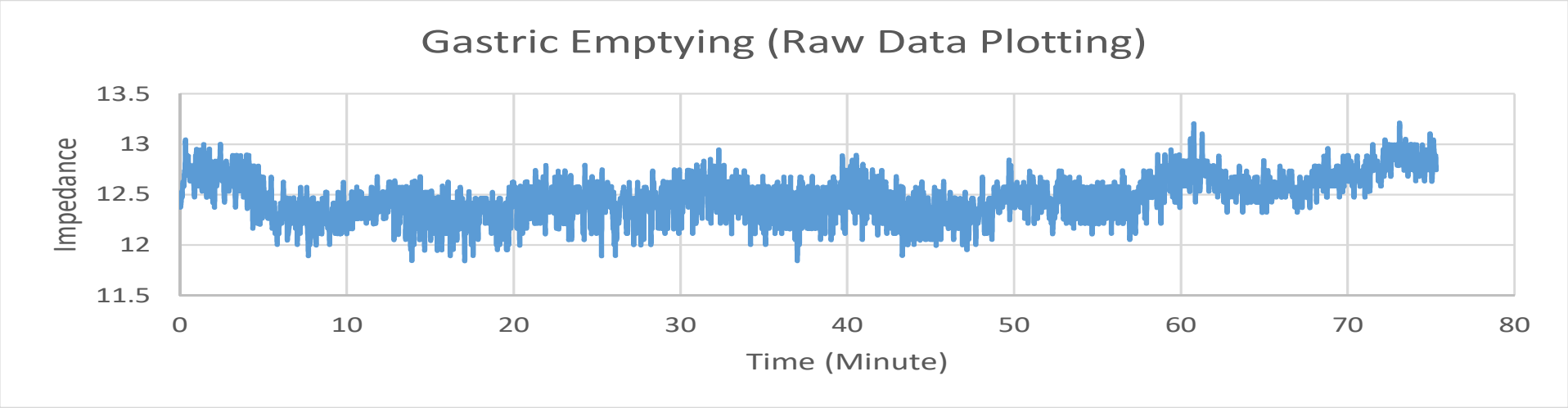


Fig. 4.11 Gastric impedance raw data in one patients

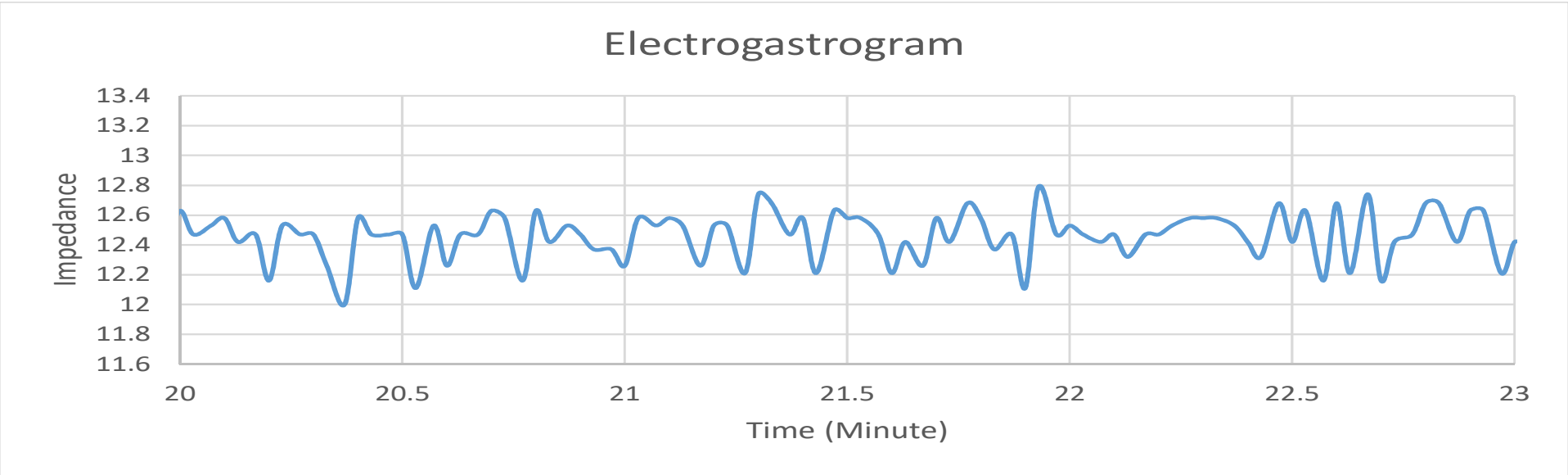


Fig. 4.12EGG recording provide the SW information in terms of rhythmicity, frequency, amplitude and propagation in single patient (Moving average plotting)

Discussion

- Thus the present work establishes an important step in the noninvasive measurement of the gastric volume inside the stomach, with important implications in the research, diagnostic and management of critically ill patient.

- The existing techniques of measuring GRV include scintigraphy (using radioactive materials), paracetamol absorption test, breath tests, ultrasoundand refractometry. they can be expensive and some of these may cause harm to patients, hence they are not feasible for use in clinical areas.

- Till now no study has been done using FIM to observe the gastric impedance changes in critically ill patient or in measuring the gastric volumes quantitatively.

- TPIM and FIM methods both seem to be capable of measuring stomach content insome way.
- The present work is just a preliminary work to show the feasibility of using TPIM with more than one electrode separation in measuring stomach, and the nasogastric suction method was chosen for comparing the results in view of its simplicity.
- The next phase of work should concentrate on the accuracy of this measurement.

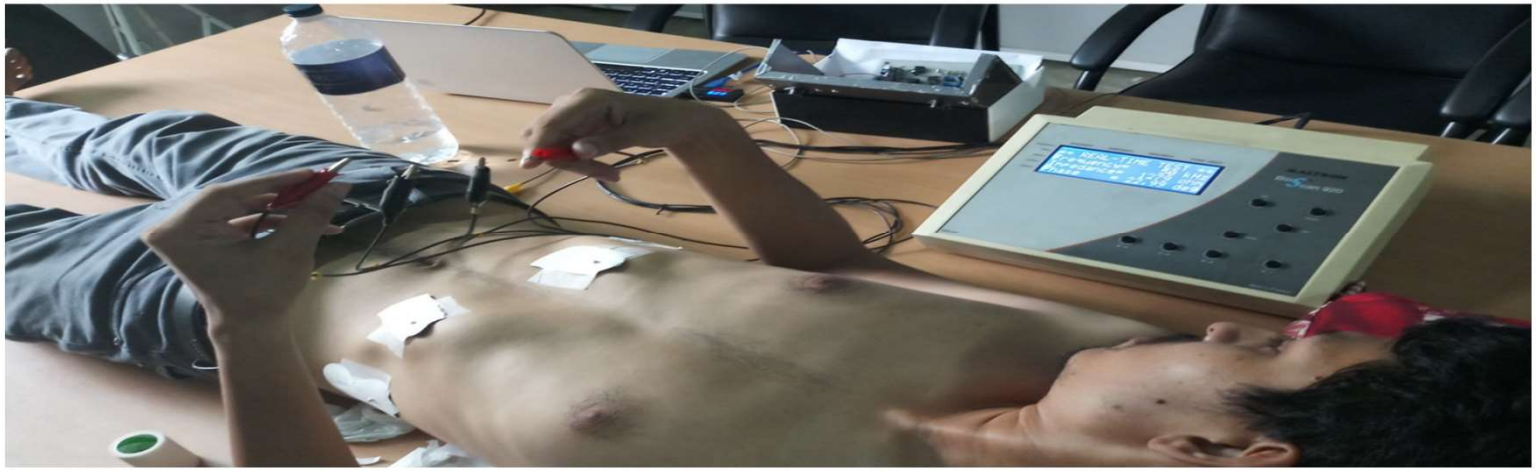
- However, another signal of interest is electro gastrography (EGG) which can be recorded from the stomach region using very sensitive and noise free recording system, having very high amplification.
- EGG is related to gastric motility which may be correlated with gastric emptying.
- Therefore, an attempt should be taken to record EGG signals and measure electrical impedance values relevant to the stomach simultaneously.
- It is expected that a combination of electrical impedance and electro gastrography may give results with enhanced confidence.

Limitation

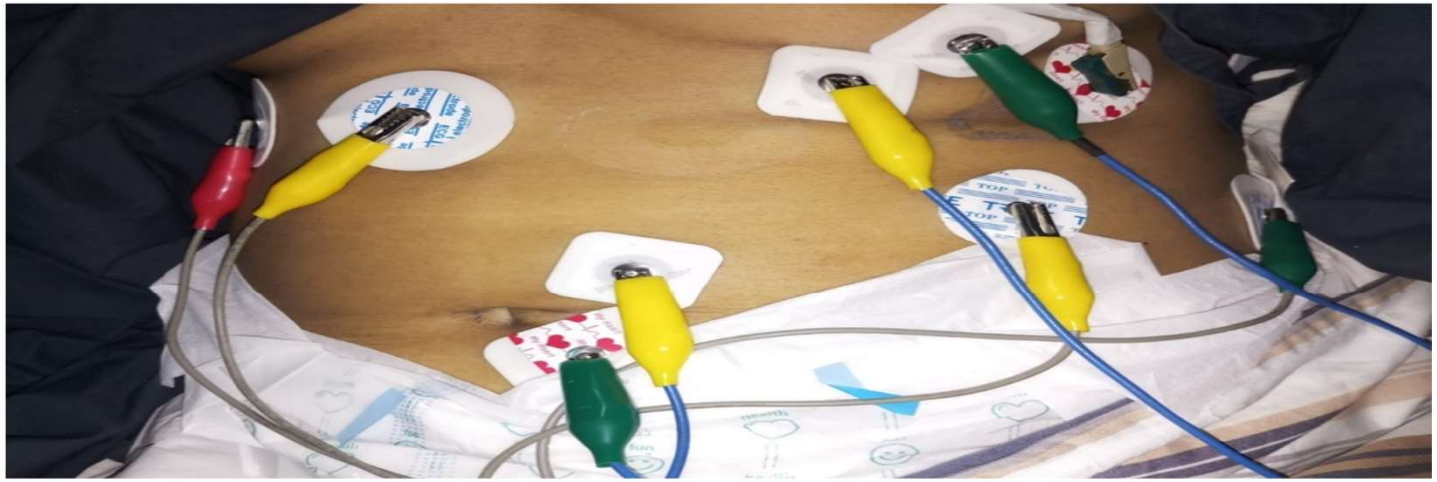
Improvement of instrument like tuning of filter for noice reduction, placement of electrode by using USG guided anatomical position of stomach and increasing impedance range.

PICTURE

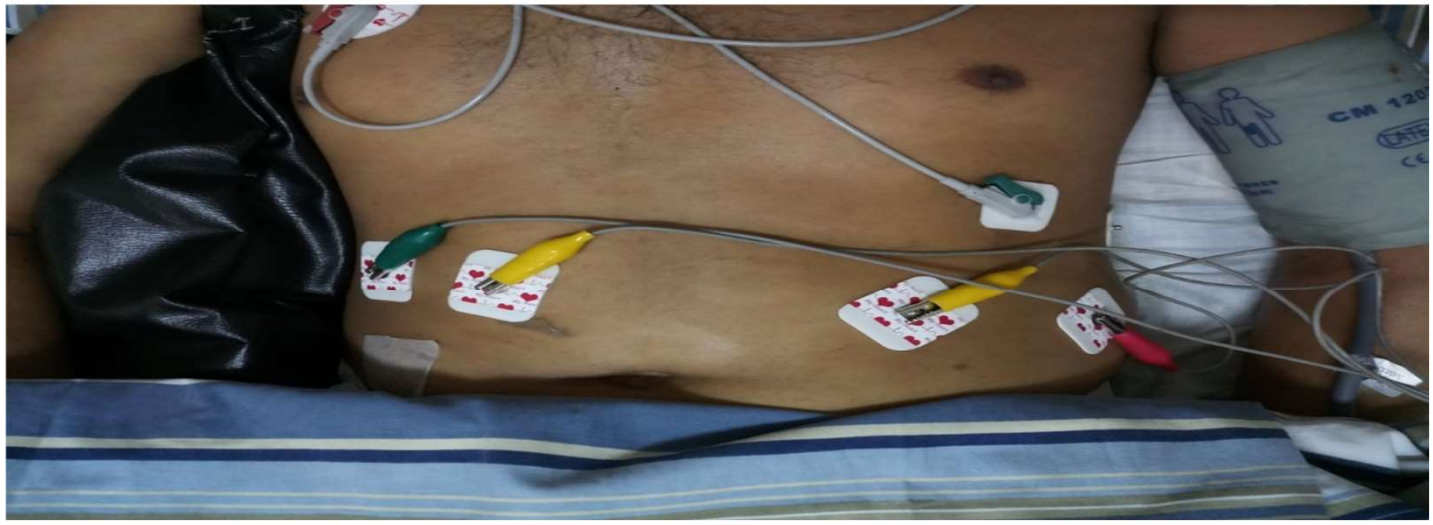
Pic-1: Impedance Machine developed by BioMedical Physics Department, University of Dhaka.



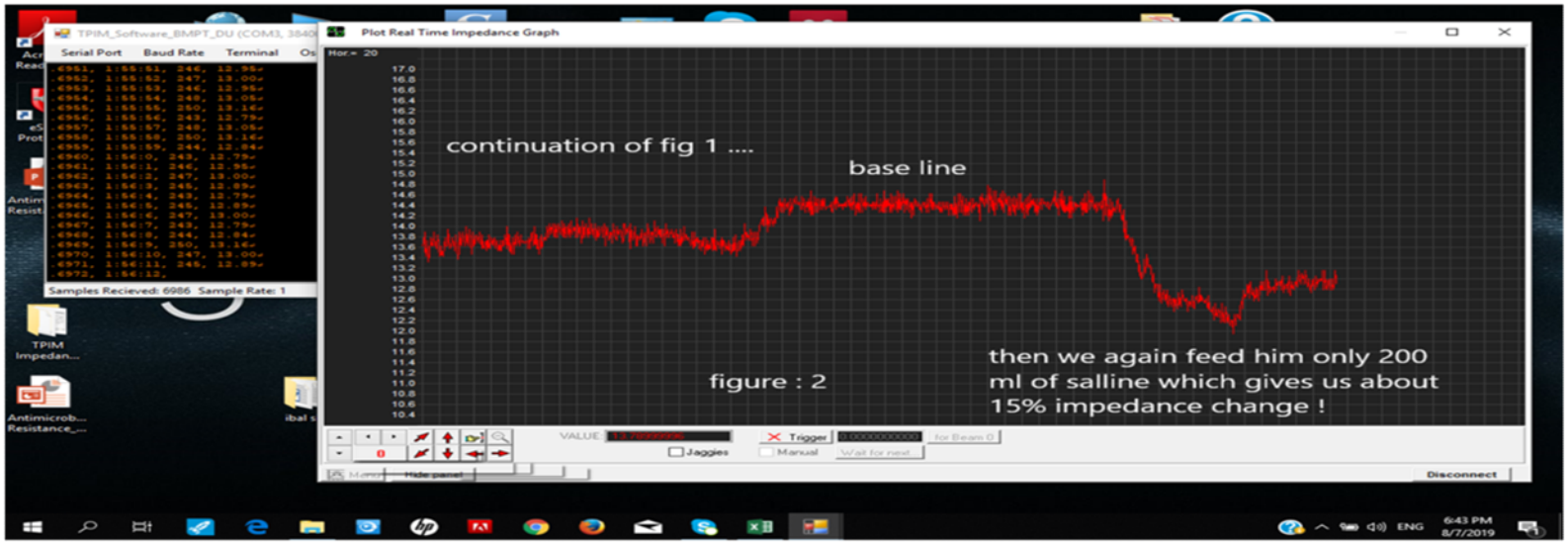
Pic-2: Calibration of impedance device was done in healthy volunteer comparing with Maltron multi frequency bio impedance analyzer



Pic-3: Eight electrode placement for FIM

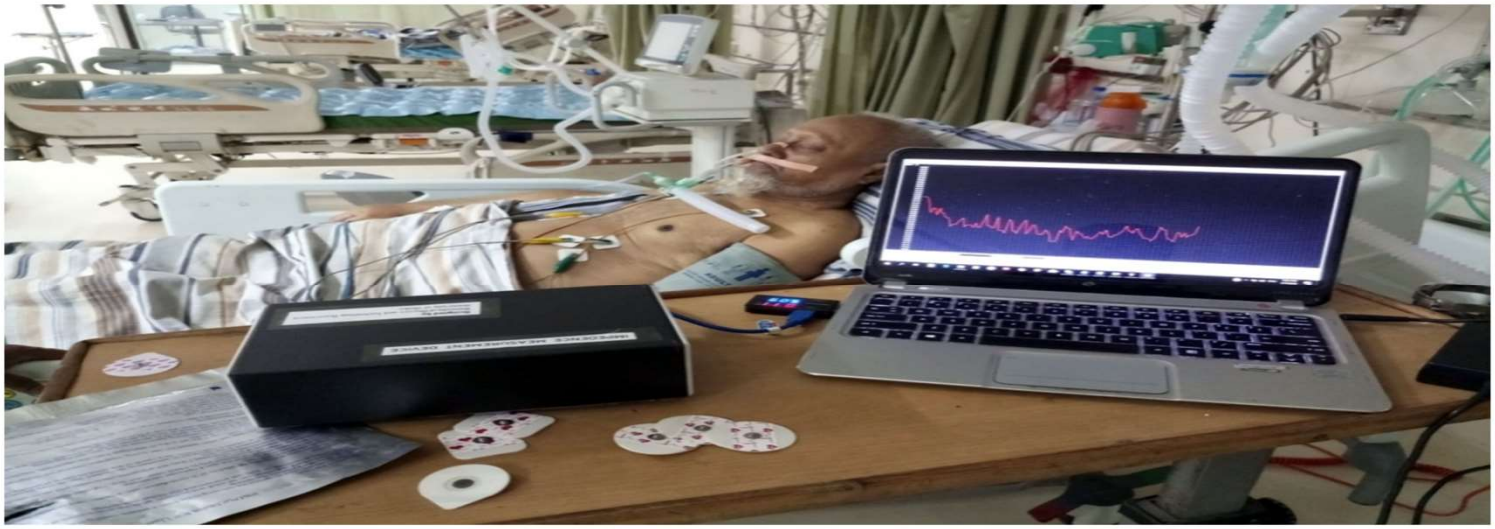


Pic-4: Four electrode placement for TPIM



Pic-5: Impedance changes after 200 ml nasogastric feeding

Pic-6: Impedance changes back to base line after nasogastric suction



Pic-7: Monitoring Impedance changes in critically ill mechanically ventilated patient using four electrode.

Pic-8: Monitoring Impedance changes in critically ill mechanically ventilated patient using eight electrode.