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**Does Emergency Medicine training  
improve ECG interpretation skills in  
South Africa?**

**MMed. Emergency Medicine  
University of Cape Town 2009**

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Student number: DJGJAC002**

## DECLARATION

I confirm that the study “Does Emergency Medicine training improve ECG interpretation skills in South Africa?” is entirely my own work.

I confirm that I hold the degree MBChB from the University of the Free State.

This dissertation is being submitted for the degree of Master of Medicine (Emergency Medicine).

I confirm that I have not submitted this dissertation for any other degree, diploma or professional qualification.

Full name: .....

Signature: .....

Date: .....

## **ACKNOWLEDGEMENTS**

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## ABSTRACT

### Objective:

The aim of this study is to assess whether ECG interpretation improves with advancing years of Emergency Medicine training in South Africa, and to compare the results with similar international studies.

### Methods:

A prospective cross-sectional study of Emergency Medicine registrars and recently qualified emergency physicians was conducted between August 2008 and February 2009 during training sessions at various universities through South Africa.

Subjects completed a survey about level of training and experience, previous ECG training and their impression of the current training program and how it could be improved. They were then asked to interpret 10 clinically important ECGs.

The trainees in their first and second years of emergency medicine training were compared to their more senior counterparts (third to fifth years).

### Results:

There were 49 completed surveys received. In this study 29/49 (59.1%) were junior trainees and 20/49 were senior trainees. The overall score in ECG interpretation was 46.4% (95% Confidence interval [CI] 41.5-51.2%). The senior group scored an average of 52.5% (95% CI 43.4-61.5%) and the junior group 42.2% (95% CI 36.9-47.5%).

### Conclusion:

There is an improvement in ECG interpretation skills between junior and senior registrars on emergency medicine training programs in South Africa. There exists, however, a low level of accuracy for many of the critical diagnoses.

The implementation of a structured ECG teaching program early during training and a greater emphasis on one-on-one teaching of ECGs should be made.

## INTRODUCTION

The use and interpretation of electrocardiograms (ECGs) is widely accepted as an essential core skill in Emergency Medicine<sup>1</sup>. Electrocardiography is a commonly used procedure for the diagnosis of heart disease. ECG abnormalities may be the first indication of ischaemia, metabolic disturbance, or life threatening arrhythmia.<sup>2</sup> The benefits of early correct diagnosis and rapid appropriate treatment have clearly been demonstrated in patients with acute myocardial infarction presenting to the Emergency Centre (EC)<sup>3,4</sup>. It is therefore imperative that Emergency Physicians are expert in ECG interpretation when they exit their training program. Specialist emergency physicians are known to improve patient outcomes for patients requiring urgent life saving interventions<sup>5</sup>; it has been shown that ECG interpretation skills improve throughout the training program in Emergency Medicine in Australia.<sup>1</sup>

South Africa is a developing country and Emergency Medicine a developing speciality. The first locally trained Emergency Physicians have only recently qualified. Presently EC staffing mostly consists of medical officers or junior doctors. In teaching hospitals in the Western Cape and Gauteng there may be Emergency Medicine registrars on duty; in most of the bigger referral hospitals consultant cover is available on site during the day and telephonically after hours. For the vast majority, the immediate medical management is initiated by the junior doctor without specialist or consultant input. This is especially true for the public health sector, and more so after hours. After hours, emergency medicine registrars are very often the most senior doctors in the EC. The final decision regarding ECG interpretation and patient management often lies with the registrar on duty. Accurate ECG interpretation by EM registrars is therefore imperative to delivering quality patient care.

Registrar teaching programs at different universities are constantly updated and developed to improve the level of training. The Fellowship of the College of Emergency Medicine (FCEM(SA)) is the exit examination for trainees;

during training towards this exam they maintain a logbook. This C.R.I.T.I.C.A.L. performance portfolio clearly states that a high skill level in ECG interpretation is a requirement.<sup>6</sup> This performance portfolio also states the training objectives for a four year rotation in Emergency Medicine. In section 4 of this document the time needed in each discipline is clearly stipulated as:

- Six months in Internal Medicine. (With a particular emphasis on cardiology, respiratory medicine and infectious diseases. A cardiology rotation is not specifically noted as a requirement in the guidelines.) The rest of the four year rotation is completed with rotations through:
  - General surgery (3 months)
  - Orthopaedic surgery (3 months)
  - Paediatrics (3 months)
  - Obstetrics and gynaecology (3 months)
  - Anaesthetics (3 months)
  - Intensive care (3 months)
  - Otorhinolaryngology, ophthalmology, psychiatry (1 month each)
  - Emergency Medical Services (3 months)
- Registrars also work in emergency medicine departments as a junior registrar (6 months) and as a senior registrar (12 months), where more practical exposure to ECG interpretation will be obtained.

It is not known whether South African Emergency Medicine trainees are getting the necessary skills in ECG interpretation during the training program.

In other countries, emergency physicians have been shown to have similar skill levels to cardiologists in emergency ECG interpretation, especially in determining ST- segment elevation.<sup>7</sup> Emergency physicians show a low rate of ECG misinterpretation in patients with chest pain and ST elevation.<sup>8</sup> It has also been shown that emergency medicine residents have similar skill levels in ECG interpretation compared to medicine residents<sup>9</sup> (although the overall performance was low for both disciplines in this study - rates of

incorrect diagnosis were 58% for complete heart block and 8% for myocardial infarction).

The American Boards of Internal and Emergency Medicine have a general requirement for staff training, initial competency evaluation and maintenance of competency in electrocardiography.<sup>10</sup> Salerne *et al* feel that determination of initial competency in ECG interpretation at the end of residency training should be based on periodic objective assessment and documentation of resident interpretation skills in a clinical context rather than completion of a minimum number of interpretations.<sup>10</sup> The American College of Cardiology and the American Heart Association have criteria that they suggest be used to assess the level of competence in ECG interpretation.<sup>11</sup> These include the following:

- 1) Board certification in cardiology, on the basis of passing an included standard examination of ECG interpretation.
- 2) Documentation of prior interpretation of 500 ECGs under supervision of an expert echocardiographer as an alternative.
- 3) Passage of the American Board of Internal Medicine Institute for clinical evaluation, ECG certifying examination.

Even though there is no clear agreement between the American College of Cardiology/American Heart Association and the American Boards of Internal and Emergency Medicine on the requirements needed to be judged as competent in ECG interpretation, both have a policy document on the subject.

Currently there are no clear criteria to assess emergency physicians' competency in ECG interpretation in South Africa. The evaluation of ECG skills is done as part of the general examination process; ECG questions form part of the written and practical evaluation of the FCEM(SA) examination.

There is no data regarding the quality of local Emergency Medicine training. It is necessary to determine whether the skill levels of locally trained Emergency Physicians are at the levels required by the College of Emergency Medicine.

## AIM

The aim of this study is to assess whether ECG interpretation improves with advancing years of Emergency Medicine training in South Africa.

Secondary aims include:

- Evaluate the accuracy of Emergency Medicine trainees in interpreting individual ECGs.
- Compare the accuracy of local trainees with overseas peers.

The following objectives are necessary to achieve this aim:

- 1) Perform a literature review of current skill levels of Emergency Medicine trainees in ECG interpretation.
- 2) Perform a literature review of the training methods used and advocated to improve ECG interpretation.
- 3) Collect information on the current level of Emergency Medicine and ECG training in the study group.
- 4) Test the level of competence of Emergency Medicine trainees in ECG interpretation.

## LITERATURE REVIEW

An internet based literature search was undertaken, using the following databases:

Medline 1968 – present

Pre-Medline

EMBASE 1982 – present

The key words *ECG*, *Emergency Medicine*, and *training* were used.

The database search found 123 related articles; 20 of the articles were deemed useful for this study. Further articles were retrieved via the Google Scholar search engine and the TRIP database using the same key words.

All related articles were assessed for suitability by abstract review. All articles deemed appropriate had their references crosschecked for relevance. More articles were identified by this method. No attempt to contact authors of articles was made, but editorial review articles were included in the literature review for the most relevant article.<sup>12</sup> Only one study with similar objectives was previously done internationally.<sup>1</sup>

## **METHODOLOGY**

### **Study design**

A prospective cross-sectional study of Emergency Medicine registrars and recently qualified emergency physicians was conducted between August 2008 and February 2009.

### **Inclusion and Exclusion**

All South African universities with training programs in Emergency Medicine were approached to join the study. All trainees on the training programs were approached and asked to consent to take part.

Only trainees enrolled in a full time four year MMed (or equivalent) rotation, or recently qualified from the program were included

Doctors who were grandfathered or admitted by peer review onto the specialist register were not approached (as the aim was to assess the current teaching curriculum and not the level of all Emergency Medicine Consultants).

Trainees refusing consent were excluded.

### **Data collection**

Collection of data took place at each university's dedicated Emergency Medicine teaching sessions.

Participation was voluntary, and a consent form was signed by all participants prior to completing the survey (appendix A). The surveys were completed under direct supervision by either the study coordinator or an appointed representative, although all completed forms were rendered anonymous prior to being assessed.

## Questionnaire

All participants completed a survey (appendix B) detailing:

- 1) The year of graduation as a doctor.
- 2) Current year of Emergency Medicine training.
- 3) Previous specific ECG training. Participants were asked to indicate in which format they received their previous ECG teaching:
  - Medical school.
  - ECG workshops.
  - Formalized ECG teaching.
  - Internet based teaching.
  - Self study.(They could select more than one option.)
- 4) The satisfaction with current ECG teaching: In this question participants were asked if they felt that the current ECG teaching is adequate. Choices ranged from poor to excellent.
- 5) A subjective assessment of training. Trainees were asked how, in their opinion, ECG teaching could be improved. This was an open question; no specific options were given.

After the survey, participants were asked to interpret ten anonymized ECGs and to write their interpretations on a standard data form (Appendix C). Marks were awarded for correctly identifying the rate, rhythm and the QRS axis. They were then asked the main diagnosis and also to describe important additional findings on each of the ECGs. Each ECG was also accompanied by an appropriate clinical scenario (Appendix D): these scenarios comprised brief descriptions of the clinical presentation, sex and age, as applicable to every ECG.

There was no time limit placed on completing the ECG interpretation. An example ECG and a pre-completed data form were provided to serve as a guide (Appendix E).

All ECGs were selected from an ECG bank. Each ECG was recorded from a real patient. All investigators and participants were blinded to the identity of the patients. The ECGs were selected by the lead investigator and deemed clinically significant to the speciality of Emergency Medicine.

All ECGs were reviewed independently by two cardiologists. The cardiologists compiled answers on standard data forms (Appendix C). In the event of disagreement, a third independent cardiologist was approached and the majority opinion was accepted as the gold standard.

The main diagnosis for the ten ECGs was: (Appendix F-O)

- 1) Antero-septal ST elevation myocardial infarct
- 2) Atrial flutter
- 3) Pericardial effusion/tamponade
- 4) Third degree atrioventricular block
- 5) Inferior ST elevation myocardial infarct
- 6) Ventricular tachycardia
- 7) Hypothermia
- 8) Wolf-Parkinson-White syndrome
- 9) Right bundle branch block with left anterior hemiblock (Bifascicular block)
- 10)Hyperkalaemia

### **Mark allocation**

The ECGs were marked independently by two qualified senior emergency physicians.

Markers were trained on the main ECG diagnosis and were provided the gold standard answers (from the cardiologists). They were blinded to the identity of the individual participants.

Each ECG was scored out of a total of ten. The average of the two scores awarded was used as the final mark.

A discrepancy of more than three in any score between the markers would be referred to one of the cardiologists for a final opinion. Each marker was blinded to the other's answers.

### **Data analysis**

Participants were divided into junior and senior groups based on their progress in emergency medicine training.

The junior group consisted of emergency medicine registrars in their first and second years of training; the senior group consisted of emergency medicine registrars in their third and fourth years of training and those qualified in the last twelve months.

The primary outcome was a comparison of the accuracy of ECG interpretation by the senior group to the accuracy of the junior group. The secondary outcome was a comparison with international standards. To do this, only the main diagnoses given by the participants were compared.

### **Statistical Analysis**

Data was captured in Microsoft Excel® (Microsoft, Richmond, VA) by the researcher. Any further analysis was done using SAS® Version 9.1.3. (SAS Institute Inc.) Frequencies and percentages were calculated for categorical data. Means and standard deviations or medians and percentiles were

calculated for numerical data. 95% Confidence intervals were calculated for the mean scores.

Based on years of training, the study group was divided into a junior and senior group. Comparing the categorical data between different groups, the Chi-Square statistic or Fisher's exact test was used. Comparing the mean values between groups the t-test was used. If median values were compared, the Kruskal-Wallis test was used. A significance level of 0.05 was used through out the analysis.

### **Ethical considerations**

Ethical approval for this study was obtained from the UCT ethics committee. REC REF 252/2008.

All participants were asked consent to take part, and completion of the assessment was entirely voluntary.

All data were entered onto a Microsoft Excel® (Microsoft, Richmond, VA) database and stored on a password protected work computer.

Answers to the ECGs will be presented to the registrars after completion of the project, together with a tutorial on ECGs.

## RESULTS

### **ECGs: Cardiology opinion**

The two cardiologists agreed completely on the ECG findings of nine ECGs; there was a minor disagreement on the diagnosis of ECG number three. The third cardiologist provided another blinded opinion and the ECG was assessed by the majority opinion.

### **ECGs: Marking**

There were no differences of more than three marks between the two examiners; therefore the third assessor was not needed.

### **Returns**

At the time of the study, there were 55 eligible trainees (or Junior Consultants) in South Africa. A total of 55 assessments were distributed; 50 were returned (91%) and 49 were fully completed (89%).

Of the returned assessments, 35 (71.4%) were completed by Western Cape trainees and 14 (28.6%) were received from other provinces.

### **Seniority**

The earliest graduate from medical school was in 1993 and the latest graduates were in 2005. The mean length of time since graduation from medical school was eight years – table 1. Most of the registrars (85%) in the senior group graduated from medical school prior to 2002. In the junior group 66% of the registrars graduated after 2002. There was a clear statistical difference in year of graduation between the junior and senior groups ( $p=0.0067$  [Fischer's exact test]) – table 2.

Graduation year	Frequency	%	Cumulative Frequency	Cumulative %
1993	1	2.0	1	2.0
1995	1	2.0	2	4.1
1996	1	2.0	3	6.1
1997	3	6.1	6	12.2
1998	1	2.0	7	14.3
1999	6	12.2	13	26.5
2000	8	16.3	21	42.9
2001	6	12.2	27	55.1
2002	7	14.3	34	69.4
2003	6	12.2	40	81.6
2004	6	12.2	46	93.9
2005	3	6.1	49	100.0

Table 1: Number of participants for each graduation year.

Graduation Year	Group		Total
	JUNIOR	SENIOR	
1993	1	0	1
1995	0	1	1
1996	0	1	1
1997	2	1	3
1998	0	1	1
1999	1	5	6
2000	3	5	8
2001	3	3	6
2002	4	3	7
2003	6	0	6
2004	6	0	6
2005	3	0	3
<b>Total</b>	29	20	49

Table 2: Year of graduation by group.

### Emergency Medicine training

From the 49 returns received, 29 were in the junior group, and comprised of 21 first year registrars and eight second year registrars. The senior group consisted of seven third year, six fourth year and seven fifth year registrars / junior consultants.

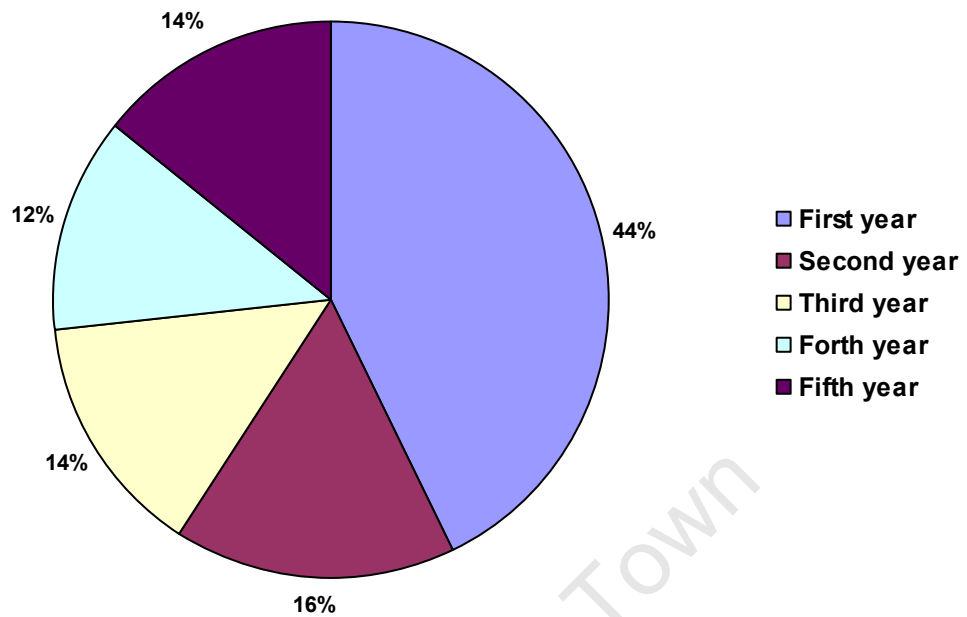


Figure 1: Respondents by year group in EM training.

### ECG training

Respondents were asked about their previous ECG training. Forty four (90%) stated that they received ECG training in medical school. ECG workshops formed part of ECG training for five registrars (10%). Only seven (14%) claimed to have received formal teaching in ECG interpretation skills after medical school. Seven participants (14%) made use of internet teaching tools. Thirty six registrars made use of self-study methods. Statistical analysis of the answers given by registrars about their previous ECG training showed that there were no significant differences between the previous ECG training of the junior and the senior groups.

ECG training	Junior Group (n)	Senior Group (n)	p-value
Medical School	27	17	0.39
ECG workshops	2	3	0.39
Formalized teach	4	3	1
Internet based	5	2	0.69
Self study	20	16	0.39

Table 3: Previous ECG training.

### **Adequacy of ECG training**

When asked whether they felt that ECG teaching was adequate on the Emergency Medicine rotation, they responded as follows:

- Seven (14%) felt that the training was poor with no ECG teaching taking place.
- Twenty three (47%) felt that they had to mostly rely on self-study.
- Eight (16%) judged the level of teaching at a moderate standard.
- Six (12%) scored the ECG training as good, but can improve.
- Three (6%) felt the ECG teaching was of an excellent standard.
- Two registrars declined to answer. No statistical difference was noted between the junior and senior groups. (p=0.39)

### Adequacy of teaching.



Figure 2: The adequacy of ECG teaching as perceived by the registrars.

### Improvement of ECG teaching

In the final question of the survey respondents were asked how they felt the level of teaching could be improved. Thirty requests were made for more formal lectures; fifteen requests for teaching at the bedside were made. ECG workshops as a teaching method were deemed useful by 12 registrars. A cardiology rotation or cardiology input was requested by eight; only four were of the impression that internet based ECG teaching would be helpful. The junior and senior groups had similar suggestions on how to improve the level of teaching, as can be seen by the table below.

Suggestion	Junior group (n)	Senior group (n)	p-value
Formal lectures	17	13	0.86
Bedside teaching	10	5	0.29
ECG workshops	6	6	0.63
Cardiology	3	5	0.43
Internet based	3	1	0.62

Table 4: Improvement of level of teaching.

## Results of ECG interpretation

### Overall

In this study, we found the overall average of ECG interpretation was 46.4% (95% confidence interval [CI] 41.5-51.2%). The junior group had an overall average of 42.2% (95% CI 36.9-47.5%), while the senior group managed 52.5% (95% CI 43.4-61.5%).

There was an improvement in ECG interpretation between the junior and the senior groups in this study. ( $p=0.035$  [t-test])

On interpretation of the main diagnosis alone, we found an overall average of 40.1% (95% CI 34.1-46.1%); for the junior group it was 34.5% (95% CI 28-41%) and the senior group 48.4% (95% CI 37.4-59.4%).

There was a significant improvement in identifying the main diagnosis of each ECG between the junior and senior groups. ( $p\text{-value} = 0.02$  [t-test])

### Individual ECGs

Results for the interpretation of each ECG are shown in figure 3 and table 4 to 6. The senior group outperformed the junior group in all except the first ECG.

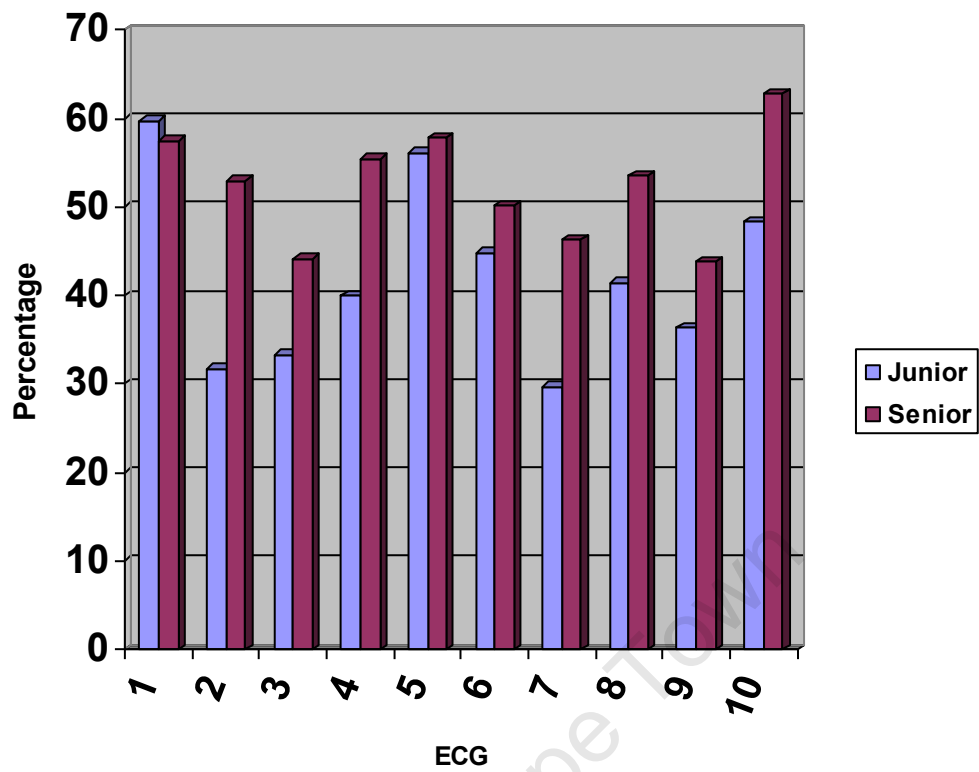


Figure 3: Individual ECG interpretation scores.

Variable	Mean correct	Std Dev	Minimum	Maximum	Lower 95% CI for Mean	Upper 95% CI for Mean
<b>Question 1</b>	58.9	14.4	0	85.0	54.7	63.0
<b>Q2</b>	40.4	25.3	0	90.0	33.1	47.7
<b>Q3</b>	37.8	22.4	0	95.0	31.3	44.2
<b>Q4</b>	46.3	24.8	0	90.0	39.2	53.5
<b>Q5</b>	56.8	20.2	0	90.0	51.0	62.6
<b>Q6</b>	47.0	20.4	0	90.0	41.2	52.9
<b>Q7</b>	36.4	23.2	0	90.0	29.8	43.1
<b>Q8</b>	46.3	25.9	0	90.0	38.9	53.8
<b>Q9</b>	39.4	18.7	0	85.0	34.0	44.8
<b>Q10</b>	54.3	29.2	0	90.0	45.9	62.7
<b>Mean</b>	<b>46.4</b>	<b>16.9</b>	<b>0</b>	<b>82.5</b>	<b>41.5</b>	<b>51.2</b>

Table 5: Individual ECG interpretation by whole group. (n=49)

Variable	Mean correct	Std Dev	Minimum	Maximum	Lower 95% CI for Mean	Upper 95% CI for Mean
<b>Question 1</b>	59.8	12.6	35.0	80.0	55.0	64.6
<b>Q2</b>	31.7	19.6	5.0	75.0	24.3	39.2
<b>Q3</b>	33.3	17.4	10.0	80.0	26.7	39.9
<b>Q4</b>	40.0	24.2	0	90.0	30.8	49.2
<b>Q5</b>	56.2	20.3	10.0	90.0	48.5	63.9
<b>Q6</b>	44.8	18.2	10.0	80.0	37.9	51.8
<b>Q7</b>	29.7	18.6	0	65.0	22.6	36.7
<b>Q8</b>	41.4	24.4	5.0	90.0	32.1	50.7
<b>Q9</b>	36.4	17.7	5.0	85.0	29.7	43.1
<b>Q10</b>	48.4	29.1	0	90.0	37.4	59.5
<b>Mean</b>	<b>42.2</b>	13.9	17.0	69.5	36.9	47.5

Table 6: Individual ECG interpretation by the junior group. (n=29)

Variable	Mean correct	Std Dev	Minimum	Maximum	Lower 95% CI for Mean	Upper 95% CI for Mean
<b>Question 1</b>	57.5	16.9	0	85.0	49.6	65.4
<b>Q2</b>	53.0	27.7	0	90.0	40.0	66.0
<b>Q3</b>	44.3	27.3	0	95.0	31.5	57.0
<b>Q4</b>	55.5	23.4	0	90.0	44.5	66.5
<b>Q5</b>	57.8	20.6	0	90.0	48.1	67.4
<b>Q6</b>	50.3	23.3	0	90.0	39.4	61.1
<b>Q7</b>	46.3	25.9	0	90.0	34.1	58.4
<b>Q8</b>	53.5	27.0	0	85.0	40.9	66.1
<b>Q9</b>	43.8	19.7	0	75.0	34.5	53.0
<b>Q10</b>	62.8	27.9	0	90.0	49.7	75.8
<b>Mean</b>	<b>52.5</b>	19.2	0	82.5	43.4	61.5

Table 7: Individual ECG interpretation by the senior group. (n=20)

### Averages of different year groups.

Results were also analyzed by year group.

First year registrars scored an average of 39.2% (95% CI 32.9-45.5%).

Second year registrars: 49.9% (95% CI 40.2-59.5%)

Third year registrars: 40% (95% CI 18.6-61.2%)

Fourth year registrars: 50.5% (95% CI 39.3-61.7%)

Fifth year registrars/Junior consultants: 66.6% (95% CI 56.2-76.9%)

When the averages of each year group were compared the only statistically significant difference was year four and five. (t-test procedure)

Variable	P - value
1 vs. 2	0.06
2 vs. 3	0.31
3 vs. 4	0.33
4 vs. 5	0.02

Table 8: Comparison of total average between different year groups.

Group	Year 2	Year 3	Year 4	Year 5
Year 1 vs.	0.06	0.92	0.079	< 0.0001
Year 2 vs.	-	0.30	0.92	0.01
Year 3 vs.	-	-	0.33	0.02

Table 9: Further comparison of total average between year groups.

### Main diagnosis

The correct interpretation of the main diagnosis in isolation by the different year groups had similar results. The only statistical difference was between year group four and five.

Year group	Median	25 <sup>th</sup> percentile	75 <sup>th</sup> percentile
1	26.67	21.67	38.33
2	36.1	27.5	56.9
3	35.3	6.7	50.2
4	41.1	33.6	65.3
5	75.2	53.6	80.3

Table 10: Main diagnosis for each year group.

<b>Variable</b>	<b>P - value</b>
<b>1 vs. 2</b>	0.09
<b>2 vs. 3</b>	0.64
<b>3 vs. 4</b>	0.57
<b>4 vs. 5</b>	0.03
<i>Kruskal-Wallis Test</i>	

Table 11: Comparison of main diagnosis between year groups.

<b>Group</b>	<b>Year 2</b>	<b>Year 3</b>	<b>Year 4</b>	<b>Year 5</b>
<b>Year 1 vs.</b>	0.09	0.92	0.10	0.0004
<b>Year 2 vs.</b>	-	0.64	0.8	0.010
<b>Year 3 vs.</b>	-	-	0.57	0.004

Table 12: Further comparison of main diagnosis between year groups. (Kruskal-Wallis Test)

University of Cape Town

## **DISCUSSION**

### **Survey**

#### **Seniority**

In the study group the senior group had generally qualified prior to the junior group as medical doctors. The senior group may therefore have had more exposure to ECG interpretation. The senior group scored higher than the junior group on interpretation of the ECGs. It is not certain if the higher scores obtained by the senior group are due to training in emergency medicine or due to more clinical experience only. The data collected in this study suggests that most of the growth in ECG interpretation took place between year four and five of training. This may suggest that preparation for the emergency medicine exit examination improves ECG interpretation more than experience alone.

#### **Previous ECG training**

Both the junior and senior groups had previous ECG training in medical school or by self-study methods. Only small numbers reported formal ECG training, ECG workshops and computer based training. These three areas should be addressed during the Emergency Medicine rotation. Both groups had similar types of previous ECG training and this should not have an effect on the results. The exception being the amount of time the senior group had to do self-study, compared to the juniors.

#### **Adequacy of ECG training**

Both groups felt the current level of ECG training was not adequate, and that they had to mostly rely on self-study to improve their skills.

#### **Improvement of ECG training**

The biggest group of registrars requested more formal ECG teaching, bedside ECG teaching and ECG workshops during the training program.

Only eight requests for a cardiology rotation to improve ECG interpretation were made. This was an interesting finding; because there have been a lot of pressure by the Cape Town registrars to have a cardiology rotation included in the training program. The use of internet and computer based learning was not favored by the registrars. An internet based learning program (VULA) is currently in development for the training program in the Western Cape. The low level of interest by the registrars in computer based learning is may have a negative impact on the success of the program.

A search of the literature yielded a lack of publications describing standardized evidence-based methods of teaching ECGs, but instead provided only a single review and several anecdotal commentaries by recognized experts.<sup>13,14</sup> The American Board of Internal Medicine (ABIM) subspecialty board examination of cardiovascular disease taken by fellows upon completion of their fellowship training contains 2 parts: a multiple-choice test with image analysis and a 37-question test of 12-lead ECG interpretation. Candidates must pass both the multiple-choice portion and the ECG portion; therefore, good performance on the multiple-choice cannot compensate for poor performance on the ECG tracings.<sup>15</sup> In a recent survey of ECG teaching programs of cardiology trainees, most programs reported spending a total of 11 total hours per month divided among 4 specific areas:

- 0 to 4 hours of core curriculum didactic lectures,
- 0 to 5 hours of one-on-one tutorials,
- 0 to 4 hours of interactive conferences, and
- 0 to 2 hours of board review conferences.<sup>16</sup>

In the same study, 42% of fellowships interviewed formally track the number of ECGs interpreted by their trainees. Fifty eight percent of the fellowships performed a formal test of ECG competency during the training program; often annually.

There is a scarcity of data demonstrating clear superiority of any specific method of teaching ECG interpretation, but the experiences of recognized experts have led to consistent agreement that the one-on-one method is

most beneficial.<sup>17</sup> Lecture-based ECG teaching is anecdostally seen as more of an adjuvant method.<sup>17</sup>

## General

Previous studies have looked at the competency of junior doctors to interpret ECGs. Hoyle *et al* found a 56.6% overall accuracy<sup>1</sup>; Berger *et al* found a overall accuracy of 60% in ECG interpretation by Emergency Medicine and Internal Medicine residents.<sup>9</sup> Other studies showed accuracies of 36-96% in residents and non-cardiologists.<sup>10,18,19,20,21</sup>

In this study, the average score by the junior group was 42.2%. (49.6% as found by Hoyle *et al*.) The average of the senior group was 52.5%. (67.5% in Hoyle *et al*.) However, in the Hoyle *et al* study the senior group was from the 4<sup>th</sup> year upwards; this differs significantly from our study group, where the junior group consisted of 1<sup>st</sup> and 2<sup>nd</sup> year registrars and the senior group of 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> year/junior consultants. It is possible to redefine our study groups; the 4<sup>th</sup> year and higher group then scored an average of 58.5%. This is still lower than the 67.5% scored by the seniors in the Australian study, but a direct comparison is difficult due to the difference in methodology between the two studies. ECGs in our study were not similar to their ECGs. A short clinical scenario was given for each ECG in this study in this study. Studies have shown that supplying a correct clinical scenario increases accuracy of ECG interpretation.<sup>22,23</sup> It has also been shown that a misleading but plausible clinical scenario can decrease accuracy of ECG interpretation.<sup>23</sup>

In our study the focus was not only on the main diagnosis of the ECG, but also the approach to interpreting an ECG. The main diagnosis only contributed a third to the overall mark. If the main diagnosis alone was interpreted, the overall average would have been 40.1%. The juniors scored an average of 34.5% for the main diagnosis alone and the seniors managed 48.4%.

## Individual ECGs

### Question 1: A 50 year old man with chest pain.

This ECG of an anteroseptal myocardial infarction was well interpreted by the registrars with a 58.9% average. The junior group scored an average of 59.8% and the senior group actually scored less in this specific question with only 57.5%. A possible reason for the junior group doing well in this specific ECG could be the emphasis placed on correctly diagnosing ST elevation infarction in both medical school and also in the Advanced Cardiac Life Support curriculum. The ACLS Provider Course emphasizes the ST-segment elevation myocardial infarction (STEMI) and early identification of STEMI patients for rapid reperfusion in their algorithm.<sup>24</sup> The poor performance of the senior group in interpreting this basic ECG is extremely concerning. On reviewing the answers most of the trainees recognised the ECG as an ECG with ischaemic changes. Two respondents thought it was a normal ECG. Many candidates recognised that there was a myocardial infarction, but did not specifically comment that it was an ST segment elevation myocardial infarct. This could just be an omission on their behalf, but a very important detail as it changes management of the condition dramatically. The mainstay of treatment of STEMI is early reperfusion therapy achieved with fibrinolytics or primary PCI.<sup>24</sup> Some of the other incorrect or partially correct answers given was anterolateral myocardial infarction (MI), anterior MI, septal MI, posteroseptal MI and inferolateral MI.

If only the main diagnosis (point 4 on model answer) was evaluated, the junior group still outperformed their senior counterparts. They scored an average of 61.5% vs. the 54.2% scored by the senior group.

**Question 2: A 30 year old woman feeling short of breath.**

The second ECG was that of an atrial flutter with a 2:1 conduction. The average mark for all the registrars was 40.4%. The junior group scored an average mark of 31.7%, while the senior group managed a 53% average.

On the main diagnosis the juniors scored 17.8% compared to the 54.2% by the senior group. In the Hoyle *et al* study the combined accuracy of the junior and senior group for interpreting atrial flutter was 81%. The senior group in this study scored 89% and the junior group 72%.

Some of the incorrect or partially correct answers given by the registrars in our study were:

- Supraventricular tachycardia (diagnosed by ten of the registrars)
- Sinus tachycardia (five of the registrars)
- Ventricular tachycardia (two registrars).
- Narrow complex tachycardia
- Inferior ischaemia
- Atrial tachycardia
- Junctional tachycardia
- Multifocal atrial tachycardia.

This ECG rhythm is a narrow complex regular tachycardia; therefore, the differential diagnosis is:

- sinus tachycardia
- supraventricular tachycardia or
- atrial flutter.

Atrial activity (flutter waves) can be found in the inferior leads at a rate of 300/minute. The atrial complexes are inverted and manifest as a “saw tooth” pattern in the inferior leads, typical of atrial flutter. Whenever the ventricular rate is 150 +/- 20 /minute atrial flutter should be strongly considered and the ECG should be scrutinized for the presence of flutter waves.<sup>25</sup>

All these features are clearly visible on this ECG and therefore only the diagnosis of atrial flutter with 2:1 conduction was accepted.

The senior group outperformed their junior colleagues by over 20% in this question. Reasons for their better performance could be numerous, but the recognition of the saw-tooth pattern and a rate of 150/min may have prompted the more experienced group to identify the flutter rhythm.

### **Question 3: A 32 year old man with chest pain.**

This ECG was that of a pericardial effusion/pericardial tamponade. The overall accuracy in interpretation was 37.8%. The junior group had an average of 33.3% and the senior group scored 44.3%. When only looking at the main diagnosis given by the registrars the junior group scored 17.2% and the seniors scored 35%. In the Hoyle *et al* study the combined accuracy for main diagnosis of pericarditis was 48% for the two groups, compared to 26,9% in this study. They did not have an ECG of a pericardial effusion in their study and a direct comparison was impossible.

The most common erroneous answer given in this study was that of a pulmonary embolism. The basis of this diagnosis was the fact that there is a sinus tachycardia, an S wave in I, a Q wave in III and inverted T waves in the inferior leads. All these features are signs of a right ventricular strain pattern, and could fit with the diagnosis of pulmonary embolism. In this ECG there is clear electrical alternance; variations in the amplitudes of the QRS complexes. Although this is not specific for pericardial effusion, the combination of chest pain in a young man, a tachycardia, borderline low voltage criteria and electrical alternance is highly suggestive of a large pericardial effusion with pericardial tamponade.<sup>25</sup>

### **Question 4: A 75 year old woman feeling dizzy.**

The fourth ECG showed a third degree heart block. The overall accuracy in interpretation of this ECG was 46.3%. The junior group scored 40%, while the senior group managed 55.5%. The main diagnosis was correctly made

by 51.2% of the junior group and by 75.8% of the senior group. The average score for the main diagnosis alone was 61.2% in this study, compared to the 88% of the Hoyle et al study.

Many of the registrars lost marks in the section where they were asked to describe additional findings on the ECG. This contributed to the big difference between the overall marks and the main diagnosis alone. Although the registrars scored low with the general interpretation of this ECG, they did well on the main diagnosis. This is somewhat reassuring as the main diagnosis of a third degree AV nodal block must prompt urgent consideration for cardiac pacing.<sup>24</sup>

Some incorrect answers given for this ECG was:

- sinus bradycardia
- first degree and
- Second degree AV nodal block.

On this ECG there is evidence of independent atrial and ventricular activity. The PR interval varies randomly and there is no evidence that any of the P waves are conducted to the ventricles. This would then confirm the diagnosis of a complete (3<sup>rd</sup> degree AV nodal) heart block.<sup>25</sup>

#### **Question 5: A 66 year old woman complaining of heartburn.**

This ECG demonstrated an example of an inferior ST segment elevation myocardial infarct. The overall accuracy in interpretation for this ECG was 56.9%. The junior group had an accuracy of 56% and the senior group 58%.

The main diagnosis was correctly made by 51.2% of the junior group and by 53.3% of the senior group. In the Hoyle et al study the acute myocardial infarction was correctly identified by 91% of participants. In their study they did not specifically comment on the type and anatomical location of the myocardial infarct. In our study 44/49 (89.8%) registrars correctly made the diagnosis of a myocardial infarct. They did not indicate the anatomical location of the infarct and did not comment that it was a ST elevation myocardial infarct (STEMI). This led to the much lower scores. It is

important to be able to identify the anatomical location of ischaemia or infarction on an ECG as this will guide your clinical management. For example, if one notes an inferior STEMI it is important to consider the possibility of right ventricular involvement as this could have an impact on the decision to give or withhold nitrates. Hypotension after nitrate administration may be anticipated in patients with known RV infarction, and in such patients, nitrates should be administered carefully.<sup>26</sup> As discussed in question 1 identifying STEMI against non ST-elevation myocardial infarction is important, because a STEMI needs early reperfusion. The similar scores obtained by both groups in this question may again be due to the teaching at medical school and ACLS principles.

**Question 6: A 66 year old male with chest pain.**

In this very rarely captured phenomenon the patient went from a sinus rhythm into a ventricular tachycardia. The overall accuracy in interpreting this ECG was 47.1%. The junior group had an average of 44.8% and the senior group scored 50.5%. When looking at the main diagnosis alone, the junior group scored 58.6% and the senior group scored 62.5%. In the study by Hoyle et al the combined accuracy for interpreting ventricular tachycardia was 40%.

Incorrect answers given by the registrars were:

- Ventricular fibrillation
- Torsade de pointes
- Supraventricular tachycardia.

When the ECG rhythm is a wide complex regular tachycardia, the differential diagnosis includes:

- Sinus tachycardia (ST) with aberrant conduction
- Supraventricular tachycardia (SVT) with aberrant conduction and
- Ventricular tachycardia (VT).

Sinus tachycardia is ruled out based on the absence of regular association between atrial and ventricular complexes. The distinction between SVT with aberrant conduction is sometimes difficult. The presence of AV dissociation excludes the diagnosis of SVT. The presence of a rightward axis strongly favors the diagnosis of a ventricular tachycardia.<sup>25</sup>

In our study we outperformed the Australian trainees in the diagnosis of ventricular tachycardia. Ventricular tachycardia must be recognised by emergency medicine trainees. It could easily be a pulseless arrest, where urgent high-energy unsynchronized shock should be administered.<sup>24</sup> If it should be a VT with a pulse urgent intervention will still be required to prevent the patient from suffering a pulseless cardiac arrest. Reasons for poor performance by the trainees in this question may be due to rarity of capturing a sinus rhythm progressing into a VT on a 12 lead ECG.

**Question 7: A 35 year old male with no history available.**

This is a very good example of hypothermic patient's ECG.

The overall accuracy in interpreting this ECG was 36.5%. The junior group scored at 29.7% and the senior group had an average of 46.3% for this ECG.

When looking at the main diagnosis alone the average score was 34.4%. The junior group scored 20.8% in identifying the main diagnosis, while the senior group had 52.5%. Hypothermia was not one of the ten ECGs used in the Hoyle *et al* study and a comparison is not possible.

Some of the incorrect answers given for this ECG were:

- Complete heartblock and
- Myocardial infarction.

No definite sinus activity can be seen, only possible activity in AVR, therefore complete AV dissociation cannot be proven and the diagnosis of a complete heartblock was not accepted. Hypothermia can produce ECG signs that simulate those of acute myocardial ischaemia or myocardial infarction.<sup>27</sup> J-waves (also known as Osborne waves) are positive deflections in the terminal portions of the QRS complex. The exact cause of J-waves in

hypothermic patients is unknown. Although considered highly sensitive and specific for hypothermia, J-waves are not pathognomonic for hypothermia.<sup>25</sup> In this ECG the presence of a nodal slow nodal escape rhythm and J-waves should prompt the diagnosis of hypothermia. The registrars who noticed the presence of the J-waves correctly identified the ECG as that of a hypothermic patient.

**Question 8: A 50 year old male for a routine check-up.**

This ECG is clearly one from a patient with Wolf-Parkinson-White syndrome. The overall accuracy of the registrars in interpreting this ECG was 46.3%. The junior group had an average of 41.4% compared to the 55.3% in the senior group. On main diagnosis alone the whole group had an average of 46.6%. The junior group scored 37.4% and the senior group had a 60% average. In the Hoyle *et al* study they used an ECG of atrial fibrillation with Wolf-Parkinson-White (WPW) syndrome, their results can therefore not directly be compared to a resting ECG with WPW features. They had 26% accuracy in main diagnosis for the atrial flutter with WPW ECG.

Some of the incorrect answers given by the registrars for this ECG were:

- Hyperkalaemia and
- Left ventricular hypertrophy (LVH).

WPW, the most common ventricular pre-excitation syndrome, is characterized by the triad of

- 1) Short PR-interval < 0.12 seconds
- 2) Prolongation of the QRS complex >0.10 seconds
- 3) A slurred upstroke of the QRS complex (Delta wave)

WPW can simulate ventricular hypertrophy, bundle branch block and previous myocardial infarction. Peaked T waves can also be found in pre-excitation syndromes.<sup>25</sup> In this ECG all of the above features are clearly visible. This may have led to the misdiagnoses of hyperkalaemia and LVH.

**Question 9: A 58 year old woman with chest pain.**

On the second last ECG the diagnosis was not clearly visible at a glance. If the correct steps in reviewing the ECG were followed the interpretation would have been successful. The registrars had to identify the left axis and the right bundle branch block, to notice the bifascicular block.

The overall accuracy for this ECG was 39.4%. The junior group managed a score of 36.6% and the senior group had 43.8%. For main diagnosis alone the group had an average of 32%. The junior group had 23.6% for their main diagnosis and the senior group had 34.2%.

Many of the registrars diagnosed the right bundle branch block correctly in this ECG. The bundle branch block is diagnosed by the rsR pattern in lead V1, a wide QRS complex and wide S-wave in the lateral leads. The left anterior fascicular block is suggested by the left axis. One of the most important problems related to hemiblocks is that they may simulate or conceal the electrocardiographic signs of myocardial infarction or myocardial ischaemia and may mask or simulate ventricular hypertrophy.<sup>28</sup>

**Question 10: An 85 year old woman feeling weak and tired.**

The last ECG was taken from a patient with severe hyperkalaemia.

The overall accuracy in interpreting this ECG was 54.3%. The junior group had an average of 48.6% and the senior group had 63%. In making the main diagnosis only, the registrars had an average of 58.5%. The junior group had 49.4% for the main diagnosis and the senior group 66.7%.

The good scores in the interpretation suggest that the registrars are well versed in recognizing the ECG changes in hyperkalaemia. Reasons for this might be that it is a fairly common presentation in our emergency centres. Patients often present late in their disease process and end stage renal failure patients often arrive in the emergency unit due to the shortage of space in the renal replacement programs. (In South Africa, treatment rates of 99 pmp were reported.)<sup>29</sup>

T waves associated with hyperkalaemia are typically abnormally large, they tend to be peaked and narrow based. Peaked T-waves are the earliest finding in hyperkalaemia. Their appearance does not correlate with specific potassium levels. As potassium level rise, other ECG abnormalities develop. These include P-wave flattening, prolongation of the PR interval and QRS complex, high grade AV blocks, intraventricular conduction abnormalities and finally a sine-wave appearance of the rhythm.<sup>25</sup>

Most of these are clearly visible on this ECG.

### **Limitations**

The small study group available currently in South Africa may have an influence on the final results.

The quality of ECG interpretation by individuals could be affected by other factors, like exhaustion, night duty and illness.

Supplying a clinical scenario to each ECG should have a beneficial effect on interpretation. If the scenario is misleading but plausible, it may have the opposite effect.

## CONCLUSION

In this prospective cross-sectional study of Emergency Medicine registrars and recently qualified emergency physicians, we found that there was improvement in the interpretation of ECGs between the junior and senior registrars. There exists, however, a low level of accuracy for many of the critical ECG diagnoses.

If single year groups were compared, the biggest improvement was from year four to five, where registrars are actively preparing for, or have completed, the exit exam. There was an improvement from year 1 to year 2, but not statistically significant. This improvement may be due to the training received on academic ward rounds and working in an academic environment. There is a plateau in the improvement of ECG interpretation during the middle year groups. During this time many of the registrars are focused on passing the basic sciences examinations and may not focus on improving ECG skills.

The average score of 46.4% obtained in this study is lower than the scores obtained by other international studies from countries where Emergency Medicine is a well established speciality. This is an expected result as the training program in South Africa is now only in its 6<sup>th</sup> year.

As a young program we are in the ideal position to learn from the knowledge gained by older training programs.

## RECOMMENDATIONS

- The exam in basic sciences should be a prerequisite for admission onto the training program.
- ECG training should start early in the teaching program and should consist of one-on-one training, formal lectures, ECG workshops.
- Training in the EC should take preference. This is often one-on-one, easily accessible to registrars. The clinical scenario provided may improve ECG interpretation.
- The use of computer based education should be promoted<sup>30</sup>
- Annual formal testing of ECG skills should be implemented during the training program.
- The College of Emergency Medicine should have a policy document stating the criteria needed for ECG competence.
- ECG competence should be formally tested on the exit examination and it should be seen as a critically important section.

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## APPENDICES

### Appendix A Consent form.

I am willing to partake in the study of Emergency Medicine training on ECGs.

I understand that participation is voluntary.

All answer sheets will be completed anonymously.

All information collected will be stored on a password protected computer.

Name	Date	Signature	MP number
1			
2			
3			
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30			

## Appendix B

# Survey

Please answer the following questions by either ticking the appropriate box, or supplying the information in space provided.

1. Year of graduation as doctor: \_\_\_\_\_

2. Level of Emergency Medicine training (please tick):

First year registrar	Second year registrar	Third year registrar	Fourth year registrar	5 <sup>th</sup> year registrars/Junior Consultant

3. Previous specific ECG training:  
(More than one box can be selected in this question)

Medical school	ECG work shops	Formalized teaching	Internet based	Self study

4. Do you feel ECG teaching is adequate in your Emergency Medicine rotation?

Poor - No teaching	Mostly self study	Moderate	Good but can improve	Excellent teaching

Please qualify answer: \_\_\_\_\_  
\_\_\_\_\_

In your opinion, how can the level of ECG teaching be improved? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Appendix C**

**Answer sheet**

Please answer each of the 10 questions on a separate page. Each answer sheet must correspond to the number on the top right of each ECG.

Each answer will follow a similar format.

**Question 1**

- 1. Rate: \_\_\_\_\_ /min (1)
- 2. Rhythm: \_\_\_\_\_ (2)
- 3. QRS Axis: (1)

Left Axis	Right Axis	Normal Axis

- 4. Main diagnosis (3)  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

- 5. Additional findings on this ECG: (3)  
\_\_\_\_\_  
\_\_\_\_\_

## **Appendix D**

### **Clinical scenarios**

1. A 50 year old man with chest pain.
2. A 30 year old woman feeling short of breath.
3. A 32 year old man with chest pain.
4. A 75 year old woman feeling dizzy.
5. A 65 year old woman complaining of heartburn.
6. A 66 year old male with chest pain.
7. A 35 year old male with no history available.
8. A 50 year old male for a routine check-up.
9. A 58 year old woman with chest pain.
10. An 85 year old woman feeling weak and tired.

**Appendix E**  
**Example**

## Answer sheet

Please answer each of the 10 questions on a separate page. Each answer sheet must correspond to the number on the top right of each ECG.

Each answer will follow a similar format.

**Example: ECG of sinus arrhythmia**

1. Rate:   54   /min (1)

2. Rhythm:   Irregular sinus   (2)

3. QRS Axis: (1)

Left Axis	Right Axis	Normal Axis
		x

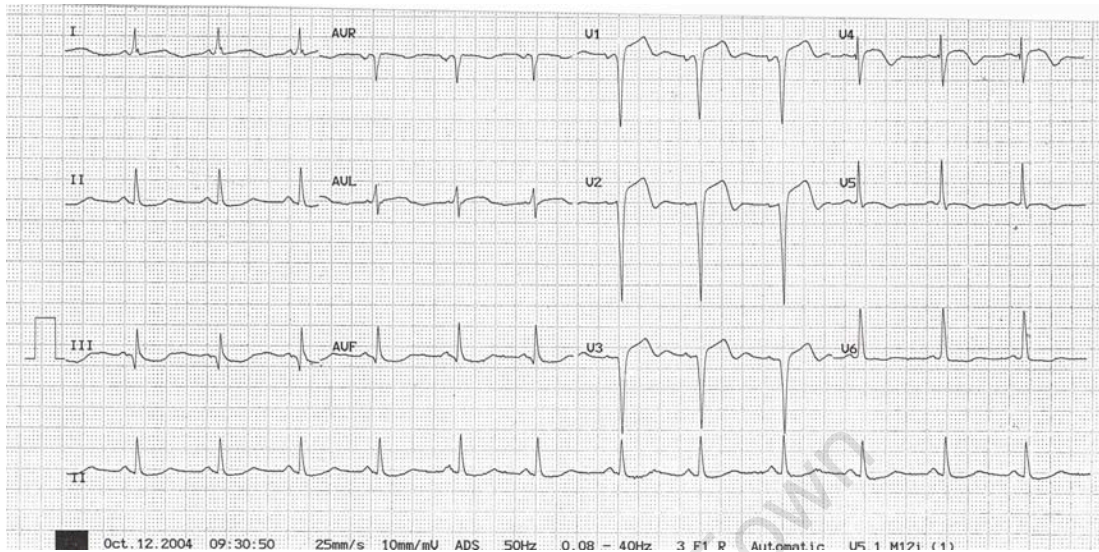
4. Main diagnosis  
  Sinus arrhythmia   (3)

5. Additional findings on this ECG: (3)

  Short P-P intervals in the beginning of the rhythm strip.    
  Longer P-P intervals towards the end of the strip.    
  Early repolarisation in leads II, III, V5 and V6.

## Appendix F

### Question 1: A 50 year old man with chest pain.



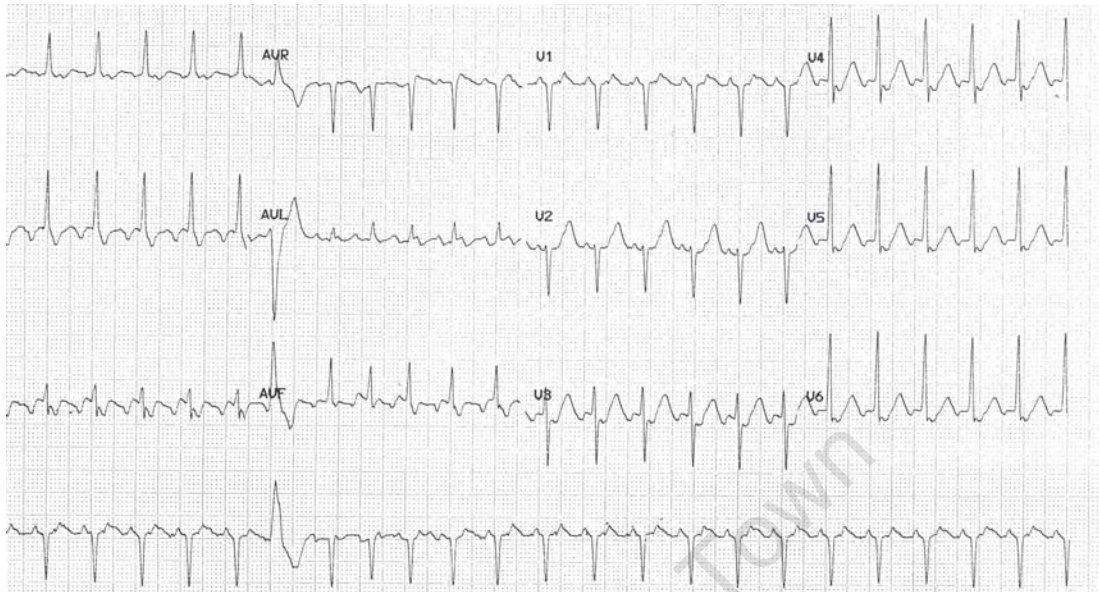
- 1) Rate: 72 /min
- 2) Rhythm: *Sinus rhythm*
- 3) QRS Axis:

Left Axis	Right Axis	Normal Axis
		X

- 4) Main diagnosis  
*Antero-septal ST elevation myocardial infarct* or  
*Subacute/recent LAD infarct (proximal vessel)*
- 5) Additional findings on this ECG:  
*Non-specific intraventricular conduction delay in lead I*  
*Left atrium dilation.*  
*Established Q-waves in V1 to V3*

## Appendix G

Question 2: A 30 year old woman feeling short of breath.



- 1) Rate: 150 /min
- 2) Rhythm: *Atrial flutter*
- 3) QRS Axis:

Left Axis	Right Axis	Normal Axis
		x

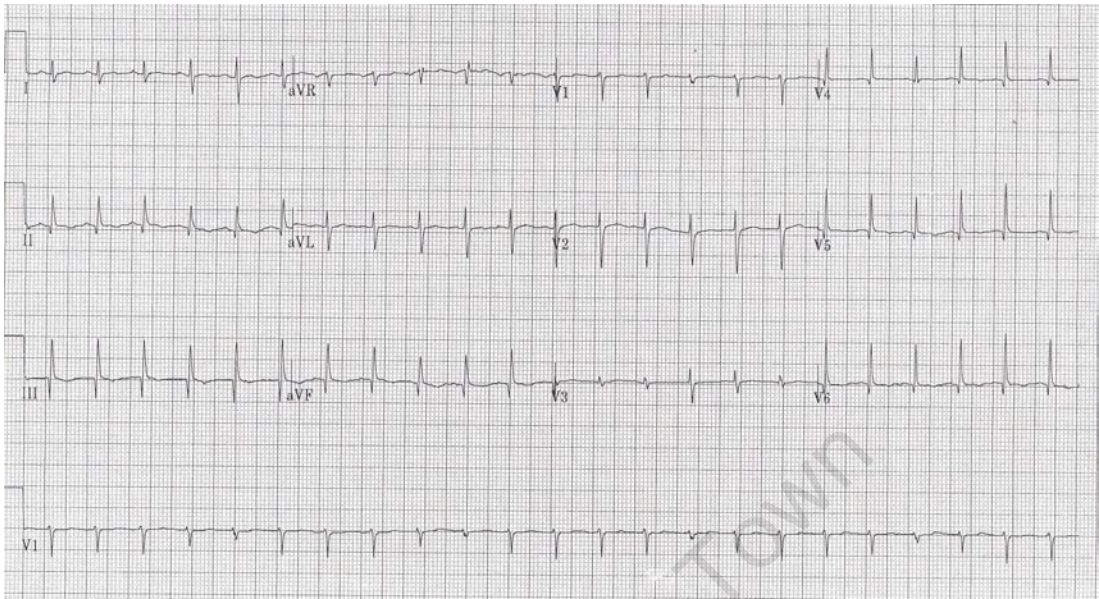
- 4) Main diagnosis  
*Atrial flutter with 2:1 conduction*

- 5) Additional findings on this ECG:

*Single PVC also seen. (Originating from the left ventricle)*

## Appendix H

### Question 3: A 32 year old man with chest pain.



- 1) Rate: 138 /min
- 2) Rhythm: *Sinus (tachycardia)*
- 3) QRS Axis:

Left Axis	Right Axis	Normal Axis
		x

- 4) Main diagnosis

*Pericardial effusion/tamponade*

- 5) Additional findings on this ECG:

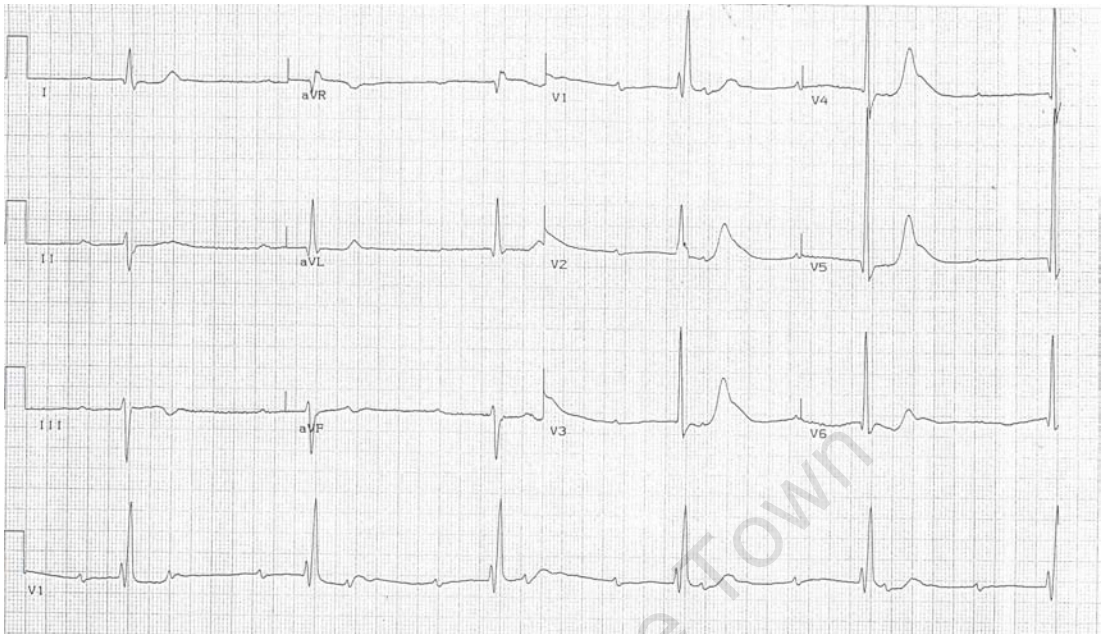
*Inferolateral repolarisation abnormality.*

*QRS electrical alternance*

*Inferior Q waves and diffuse T wave flattening.*

## Appendix I

### Question 4: A 75 year old woman feeling dizzy.



- 1) Rate: 36 /min
- 2) Rhythm: 3<sup>rd</sup> degree AV block
- 3) QRS Axis:

Left Axis	Right Axis	Normal Axis
X		

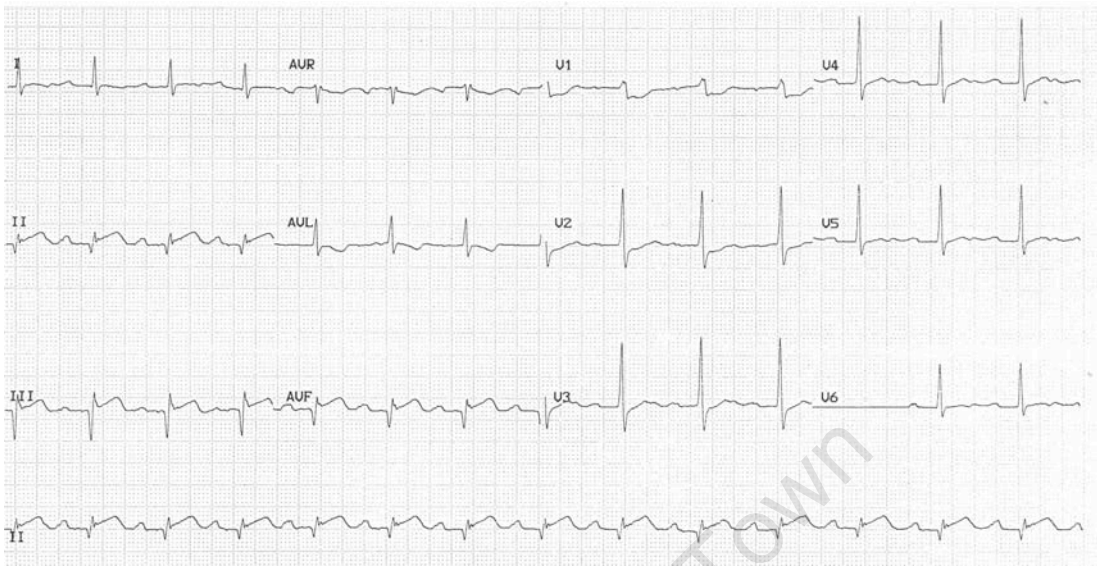
- 4) Main diagnosis
- 5) Additional findings on this ECG:

*3<sup>rd</sup> Degree heart block*

*Underlying sinus activity with total AV dissociation and ventricular escape rhythm @ 36/min showing RBBB configuration. (i.e. from left ventricle.)*

## Appendix J

### Question 5: A 66 year old woman complaining of heartburn.



- 1) Rate: 84/min
- 2) Rhythm: *Sinus rhythm*
- 3) QRS Axis:

Left Axis	Right Axis	Normal Axis
x		

- 4) Main diagnosis

*Inferior ST elevation AMI .*

- 5) Additional findings on this ECG:

*1<sup>st</sup> Degree AV block.*

*Anterior reciprocal changes ( V1 ST depression)*

*Non specific intraventricular conduction delay. (Seen mostly in inferior leads)*

*Pathological Q-waves in all three inferior leads.*

## Appendix K

### Question 6: A 66 year old male with chest pain.



- 1) Rate: 110 to 180/min
- 2) Rhythm: *Sinus to ventricular tachycardia*
- 3) Axis:

Left Axis	Right Axis	Normal Axis
	X	

- 4) Main diagnosis

*Sinus rhythm degenerating into ventricular tachycardia*

- 5) Additional findings on this ECG:

*Possible QT prolongation.*

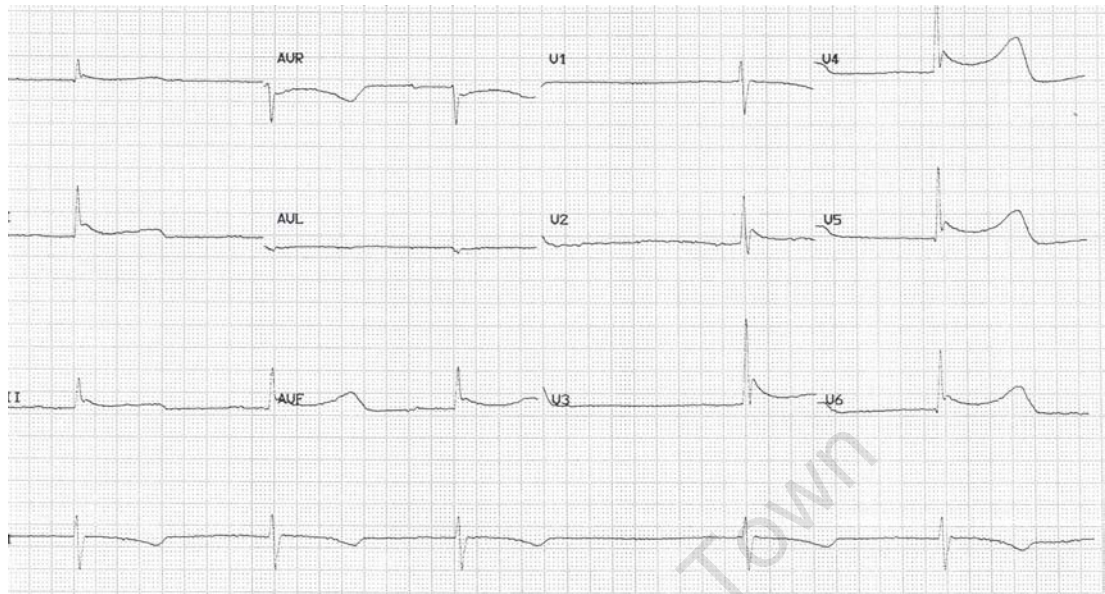
*Broad QRS complex. Right axis deviation*

*Monomorphic left ventricle VT originating from the lateral apical segments.*

*Microvoltage in extremity leads.*

## Appendix L

Question 7: A 35 year old male with no history available.



- 1) Rate: 30/min
- 2) Rhythm: *Nodal escape*
- 3) Axis:

Left Axis	Right Axis	Normal Axis
		X

- 4) Main diagnosis

*Hypothermia.*

- 5) Additional findings on this ECG:

*Possible sinus activity only seen in AVR.*

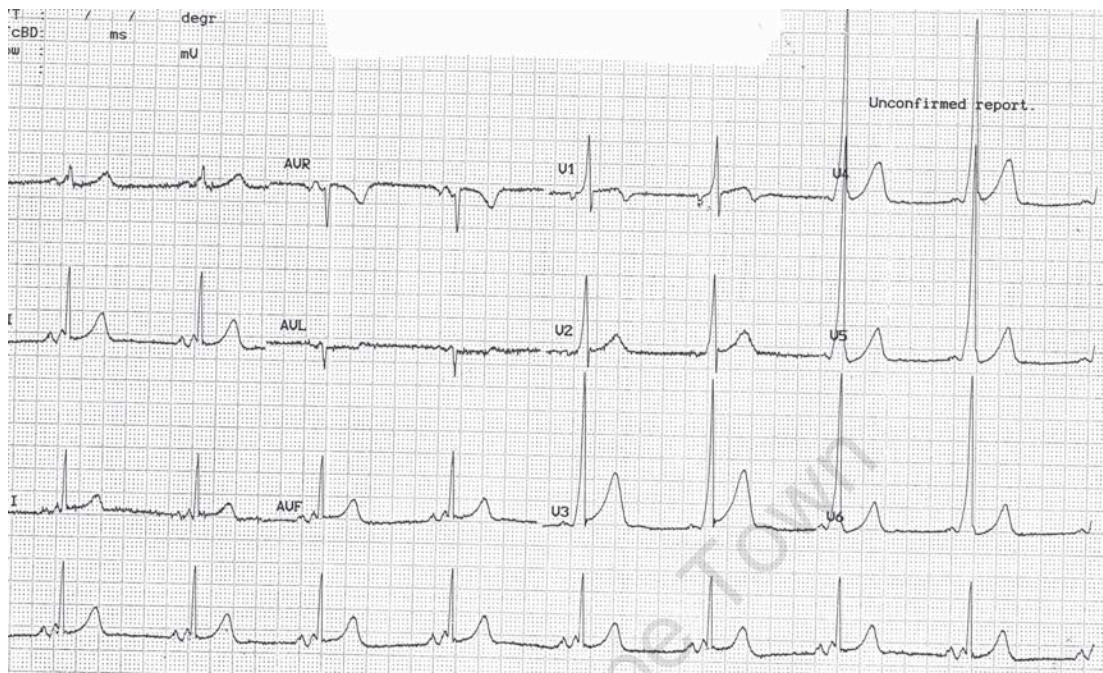
*Prolonged QT interval.*

*Camel hump sign or J wave seen especially in precordial but also in inferior leads. (Osborn waves)*

*Extreme sinus bradycardia.*

## Appendix M

### Question 8: A 50 year old male for a routine check-up.



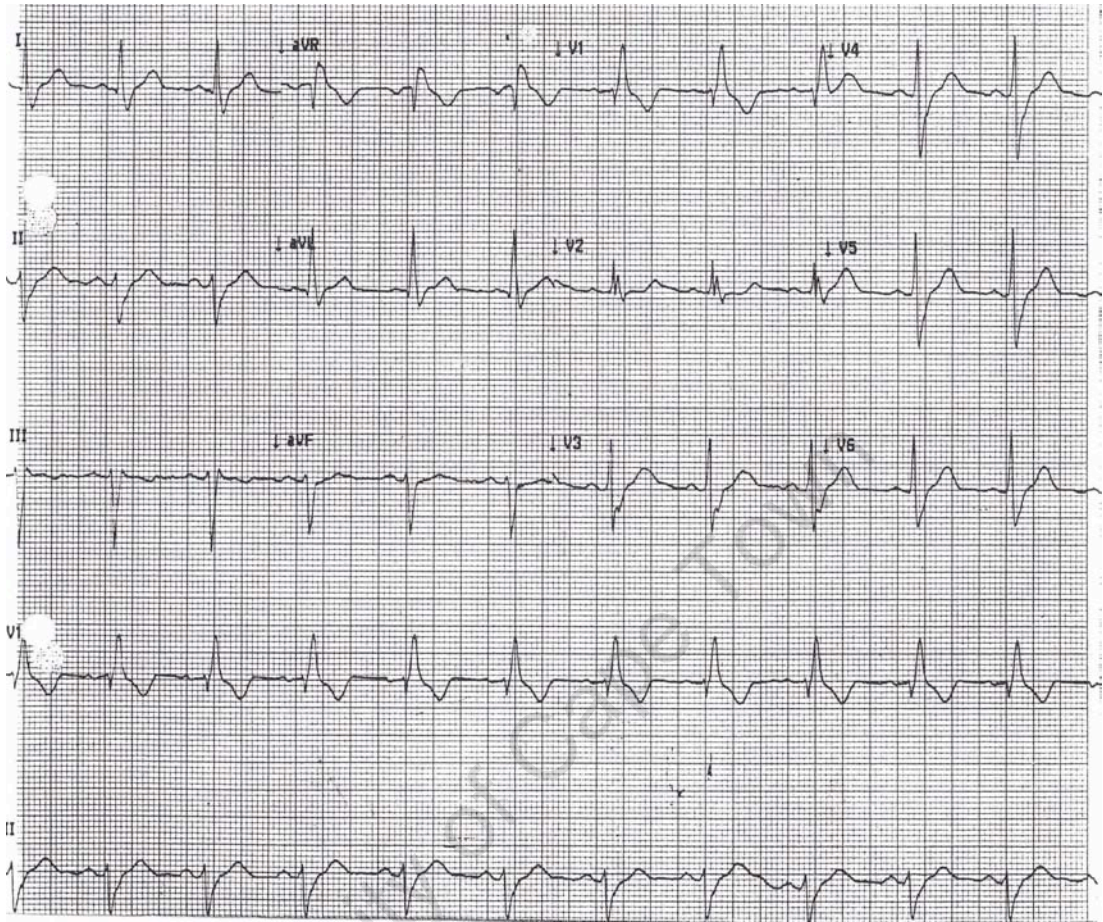
- 1) Rate: 50/min
- 2) Rhythm: *Sinus bradycardia*
- 3) Axis:

Left Axis	Right Axis	Normal Axis
		X

- 4) Main diagnosis  
*Wolf-Parkinson-White syndrome*
- 5) Additional findings on this ECG:  
*Sinus bradycardia.*  
*Clear delta waves.*

## Appendix N

Question 9: A 58 year old woman with chest pain.



- 1) Rate: 80/min
- 2) Rhythm: *Sinus rhythm*
- 3) QRS Axis:

Left Axis	Right Axis	Normal Axis
x		

- 4) Main diagnosis

*Right bundle branch block with left anterior hemiblock*

- 5) Additional findings on this ECG:

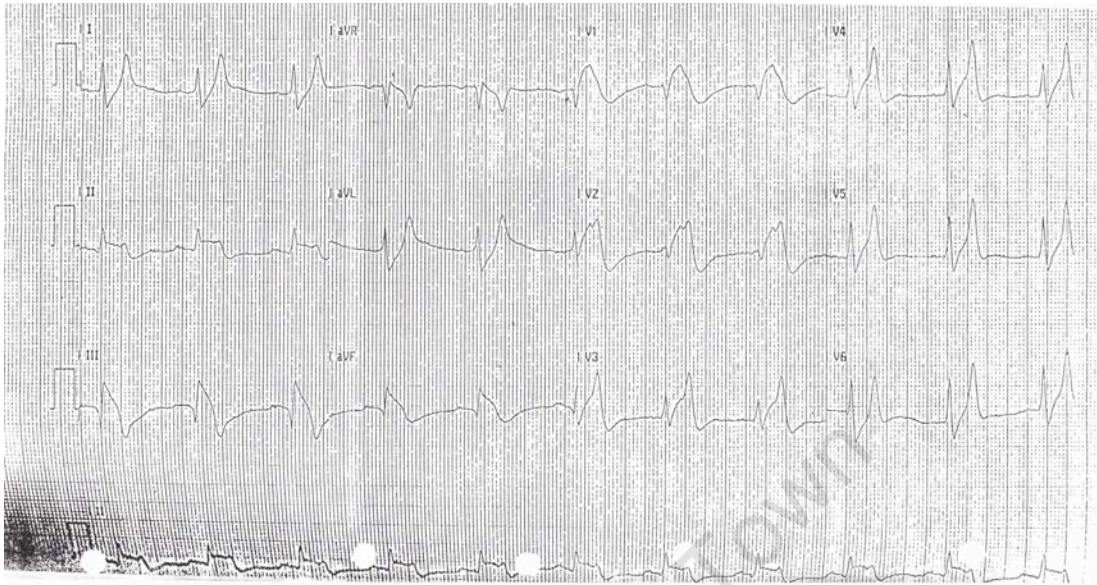
*Inferior inverted T-waves.*

*Broad QRS complex.*

*Wide lateral S waves.*

## Appendix O

Question 10: An 85 year old woman feeling weak and tired.



- 1) Rate: 60/min
- 2) Rhythm: *Sinus rhythm*
- 3) QRS Axis:

Left Axis	Right Axis	Normal Axis
		X

- 4) Main diagnosis  
*Hyperkalaemia*
- 5) Additional findings on this ECG:  
*Peaked T waves.*  
*Broad QRS complex.*  
*P waves broad and flattened.*

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