RESTING 12-LEAD ECG ELECTRODE PLACEMENT AND ASSOCIATED PROBLEMS

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While Waller is credited with recording the first human electrocardiogram (ECG) in 1887 (1), it was not until a few years later that Einthoven introduced the limb leads. In the Einthoven Museum in Leiden, in the Netherlands, there is a tracing of what is said to be Einthoven's first recording dated 1902.

Fig 1. An example of limb electrode connections from the early days of ECG recording (after Lewis 1925).

In those days, electrodes took the form of a conducting solution into which limbs were placed and therefore there was little difficulty in deciding where to attach the electrode.

Throughout the 20th Century, the process of ECG recording has been one of gradual change. The initial three standard limb leads have been extended with the introduction of unipolar chest leads and augmented unipolar limb leads. In addition, the recording apparatus has gradually changed in size and complexity so that nowadays a briefcase-sized...
A diagram illustrating the electrical activity in tissue. It shows a voltmeter connected to a positively deflected recording. The diagram includes negative and positive electrodes, depolarized tissue, tissue at rest, and the direction of the depolarizing wave.
Mechanical-Electrical Cycle
Leads

• A Lead is a picture

• You cannot point to a wire and say this lead is such...
Leads

• To measure electrical activity you need at least two electrodes

• One electrode "looking" between itself and the other electrode(s).

• By changing the position of either of these electrodes we alter the angle at which we are viewing any activity.
Leads

• The electrode doing the looking is always a single electrode.

• The "other" could be a single electrode or a number of other electrodes joined together (electrically) to form a reference point.
Preordial Leads

- E central terminal = $1/3 (EL + ER+EF)$
- Not zero, but mostly constant through cycle
- V exploring electrode = $Ep - Ect$
Precordial Lead Placement

- V1 and V2 are placed on the right and left side of sternum at the fourth intercostal space.
- Palpate the suprasternal notch
- Palpate down the manubrium until you feel a horizontal ridge (Angle of Louis)
- Articulates with the second rib. Below the second rib is the second intercostal space.
Precordial Lead Placement

- V1 (right side) and V2 (left side) locations straddle the sternum at 4th intercostal space. No eye-balling.

- V4 is placed in the 5th intercostal space in the mid-clavicular line.

- V5 is placed in a direct line with V4 at the anterior axillary line (front of the armpit).

- V6 is placed in alignment with V4 & V5 at the mid-axillary line (middle of the armpit).

- V3 is placed between V2 and V4.
Precordial Lead Placement Tips

- If the sensors cannot be placed in the usual locations, be sure to document the alternate location and why they were moved i.e. burns, surgical dressings, chest tube etc.

- Elevating the head and gravity may help positioning of large breasts or implants, otherwise under breast.

- If sensor will not lay flat (cleavage), you may need to move the V1 and V2 sensor as high as the second intercostal space.
Precordial Lead Placement

Fig 2. The positions of the six precordial electrodes. Note that the junction of sternum and manubrium is called the Angle of Louis.

The critical aspect of precordial lead positioning is to locate the fourth intercostal space. In early textbooks of electrocardiography, e.g. Goldberger (10), it was recommended that the fourth intercostal space be located with reference to the angle of Louis (Figure 2). This angle, otherwise known as the sternal angle, marks the position of the manubriosternal junction and is located where the body of the sternum proper joins the structure known as the manubrium. At this junction, there is a transverse ridge which must be identified by palpation. If the finger is moved along the ridge, it will slide downwards into the second intercostal space.

It has become commonplace for some of those who record ECGs to locate the first intercostal space by finding the clavicle and then taking the first space below as being the required interspace. Careful examination of Figure 2 will show that there is a danger in locating the small space between the clavicle and the first rib and of designating this as the first intercostal space; the first intercostal space will then be identified as the second, and so on, downwards. For this reason, it is essential to locate interspaces using the bony ridge of the angle of Louis. The consequences of not locating the fourth interspace correctly are quite significant as will be shown.

When the fourth intercostal space is identified, the six chest electrodes are then located as follows:

- V1: In the fourth intercostal space at the right sternal border.
- V2: In the fourth intercostal space at the left sternal border.
- V3: Mid-way between V2 and V4.
- V4: In the fifth intercostal space in the mid-clavicular line.
Limb Leads

• $I = EL - ER$

• $II = EF - ER$

• $III = EF - EL$

• $I + III = II$

(Einthoven Law)
Augmented Limb Leads

- $aVL = EL - (ER+EF)/2$
- $aVF = EF - (EL+ER)/2$
- $aVR = ER - (EL+EF)/2$
- $aVR + aVL + aVF = 0$
Limb Lead Placement

- Handwidth above base of the palm. If unable, use the deltoid.
- Handbreadth above medial malleolus. If unable, on the thighs.
- Stay away from large muscles due to the potential for movement and increased somatic tremor.
- Symmetry!
- Most important aspect of ecg recording is consistency of recording technique.
Frontal Plane
Patient Positioning

- Supine
- Comfortable
- Generally no pillows
- Barrier between the patient and the side rails (sheet, blanket, pillows or rail pad).
Skin Prep

• Prep the skin the alcohol swab to remove dirt, dead skin cells, oils, skin moisturizer, fake tan, body powder, sweat etc.

• Poor prep can cause poor contact with the sensors and artifacts

• Hair may need to be shaved
Cables

• Run the cables on top of the patient midline.

• Cables must lie flat on the patient, be contained within the body and not put any stress on the sensors.

• Cables that hang off the patient are susceptible to EMI and can be a source of artifact.

• Verify sensors are not peeling up or dimpled
Electrical Interference

- Tight rapid oscillations seen in the tracing which looks like a caterpillar (thick and fuzzy)
- 60-cycle AC or RF interference
- May be caused by power cords, mobile phones, lighting or electrical wires in the walls, ceiling and floor.
- Turn off lights, mobile phones off, moving away from walls and equipment, verify AC filter is ON
Electrical Interference
Wandering Baseline

- Isoelectric line changes position
Minimizing ECG Artifact

Mild skin abrasion with fine sandpaper or gritty gel effectively minimizes all types of motion and electrostatic artifact (medical products are available for this).

Respiration: Low frequency (0.4–2 Hz)

Patient Movement: Low frequency (1–3 Hz)

Transport: Medium frequency (3–15 Hz)

Muscle Tremor: High frequency (20-150 Hz) and/or medium frequency (3-5 Hz)

Muscle Tension: High frequency (20-150 Hz)

- Assure that limbs are supported and the patient is lying flat
- Ask the patient to relax
- Consider pain Rx if pain is the likely cause
- Reducing the upper cutoff frequency filter from 150 to 40 Hz reduces muscle artifact
- If shivering, cover with a blanket
- Move limb electrode elsewhere on limb to avoid culprit muscle
- Abrade skin if there is motion artifact

Identifying the culprit electrode

- If the artifact is in leads I and II but not III, the RA electrode is the source
- If the artifact is in I and III but not II, the LA electrode is the source
- If the artifact is in II and III but not I, the LL electrode is the source
- If the artifact is unique to one V lead, its V electrode is the source

Intermittent or missing leads

Intermittent Lead

- Check for dry electrodes
- Shave or clip hair from electrode site if excessive hair is present
- Alcohol wipe if skin is oily or sweaty
- Check for intermittent cable failure by trying a different cable
- For intermittent connector on ECG device, service call needed

Missing Lead

- Check for dry electrodes
- Verify that electrode and lead wire are attached to patient
- Replace worn or broken lead wire or patient cable
- For worn or broken connector on ECG device, service call needed

ECG artifact nearly always originates from sources unrelated to the monitor. The following are best practice suggestions for minimizing artifact.
Wandering Baseline

- Lose sensors--better skin prep, may need to abrade skin
- Have patient take deep breath, let half out and hold while acquiring ECG
- Cables moving
- Have patient lie still and stop talking
- Verify baseline filter is ON
Muscle Artifact

• Choppy interference throughout the tracing
• Epidermal stretch-induced voltage changes (stretching the skin changes the potential) are the primary cause of motion artifacts, and such artifacts are not filtered.
• Caused by patient movement, shivering, muscle tensioning, talking, chewing gum, etc
Muscle Artifact

Somatic Tremor
Muscle Artifact

- Warm, relaxed patient (blanket)
- Arms at patient's side fully supported
- Pain control is necessary
- Move electrode to avoid culprit muscles
Vtach Artifact
Vtach Artifact
Vtach Artifact

- Continued presence of normal QRS complexes at the cycle length of baseline rhythm within the apparent wide complexes (marked by arrows)

- An unstable baseline on the electrogram before the tachycardia events. This resulted in the recognition that the wide complexes were electrocardiographic artifacts.

- Absence of haemodynamic deterioration
Culprit Electrode

- Artifact in leads I and II but not III, the RA electrode is the source
- Artifact in I and III but not II, the LA electrode is the source
- Artifact in II and III but not I, the LL electrode is the source
- Artifact is unique to one V lead, its V electrode is the source
Lead Reversal

• Lead switches are a common mistake when ECGs are made and can lead to wrong diagnoses.

• Left-right arm reversals lead to a negative complex and negative p wave in lead I

• Arm-foot switches lead to very small signal in leads II or III

• Chest lead reversals lead to inappropriate R wave progression (increase-decrease-increase)

• Any right axis or small signal in an extremity lead should be reason enough to check lead positioning
Left-Right Lead Reversal
Left-Right Lead Reversal
Chest Lead Reversal
Monitoring

• Different purpose than 12-lead
• Looking for rhythm changes
• Choose the lead that gives the best picture of the p waves and QRS
• Often lead II, lead I or a chest lead
3-Lead Telemetry

• Lead II great for looking at apex of heart
5-lead Telemetry

- Lead II only 33% accurate in identifying SVT
- 12-lead can 90%
- V1 best single lead
Monitoring

• Monitoring leads placed on torso
• Wires to wrist and ankle tangle up patient
• Close in the voltages will be higher, but no difference in time intervals
• ST segments are not comparable to the 12-lead, but can be trended
Analyzing ECG

• Fast / Slow / Normal
• QRS side or narrow
• Regular or Irregular
• ST Segments
• Symptoms & Vital signs
Fast / Normal / Slow

• Classify the rate of the QRS complexes as bradycardic or tachycardic (or normal)

• Presence there p waves, and do the precede the QRS
Regular / Irregular

- Is the rhythm regular or irregular
- Is there a pattern to the p waves and QRS
  - Regularly irregular or irregularly irregular
- Eyeball, calipers, fold over
Wide / Narrow QRS

- 120 ms (3 small boxes)
- Narrow complexes are traveling down normal AV node route
- Wide complexes indicate pulses are talking abnormal path
ST Segments / T waves

- Ischemia -- inadequate perfusion to meet metabolic needs
- Injury -- cell death marked by troponin elevation
- Infarction -- Cell death due to prolonged ischemia
- Dynamic process
ST Segments / T Waves

- 1 mm ST Elevation in 2 contiguous leads
- 1.5mm for V2/V3 for women
- 2mm for V2 / V3 in men >40
- 2.5mm for V2 / V3 in men < 40
- Reciprocal changes / Dynamic T waves
- ST Depression
Symptoms & Vital Signs

• What is the patient telling me?

• Is there -- hypotension, chest pain, SOB, hypoxia, abdominal pain

• How can I put the ECG together with this patient?
Putting It All Together

- Bradycardia — Sinus bradycardia, junctional escape, ventricular escape
- Irregularly irregular rhythm — atrial fibrillation, multifocal atrial tachycardia, wandering atrial tachycardia
- Wide QRS — VTach, ventricular rhythm, RBBB, LBBB, drug effects, Hyperkalemia