Electrophysiology Study and Catheter Ablation
What Every Patient Needs to Know

Cardiac Health System
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ELECTROPHYSIOLOGY: THE BASICS

You may not realize it, but you have almost certainly had a form of baseline Electrophysiology Study (EPS) already. You had it when your Family Physician, General Cardiologist or Electrophysiologist requested an Electrocardiogram (ECG).

A Standard 12-lead ECG, also showing two channels for Rhythm Analysis

The ECG represents the first clinically useful tool for heart rhythm diagnosis, invented over 100 years ago. ECG principles are used for every manner of heart monitor: Holter Monitors, Telephone Loop Recorders and in-hospital continuous Telemetry. These all provide increasingly lengthy monitoring/recording intervals but do so at the expense of data limitation at any given time: whereas an ECG record 12 to 15 channels of information, Holter monitors have 2-3 and Telephone Loop Recorders only 1-2.

Strip from 2-week monitor. Note how there is only one channel of information available, compared to the 14 in the ECG above.
Bear in mind, however, that the ECG is not directly recording the heart's electrical activation, but is really a summation of all the simultaneous electrical activation as viewed from the perspective of any one particular channel, or lead. Thus, the same wavefront of activation can look quite different from any one of the many ECG channels.

The electrodes on the arms and legs were the first ECG configuration. They are used directly but also summated for "augmented" leads, making six total channels for recording.

The chest, or precordial, electrodes provide another recording option adding 6 further channels of information.
Arguably, however, the ECG remains the single most important test in Electrophysiology because it is:

A) inexpensive
B) widely available
C) fast
D) easily done
E) safe

The vast majority of Electrophysiology diagnoses start with the humble ECG.

Nevertheless, the ECG has several critical limitations:

A) it is passive - it must record whatever happens to be occurring in the heart at that very moment.
B) it is external - it records summated electrical vectors through the chest wall and lungs, compromising signal quality and precision
C) it is diagnostic only - it only begins the therapeutic process

Holter monitors and Telephonic monitors improve the diagnostic yield through lengthier monitoring periods, but remain passive and external in their capacities.

Episode of Atrial Fibrillation captured during 2-week monitor ordered to investigate unexplained Stroke. This patient will require anticoagulation.
THE HEART: AN ELECTRICAL ORGAN

When people think about the heart, most think of it first and foremost as a muscle. That’s fair, because the muscular component is what you feel when the heart ‘beats’ or contracts; it’s what makes the pulse that can be felt in the neck or in the wrist, for example. Popular depictions of the heart generally focus on the muscular component.
That the heart has its own dedicated blood supply - the coronary arteries and cardiac veins - is also relatively well understood. The four internal valves are generally appreciated. The entire system, however, only works because of the activation of the muscle by the heart's own dedicated electrical, or conduction, system. This is the Electrophysiology of the heart.

Stylized depiction of the major components of the cardiac conduction system.

Apart from the valves and their rings, the heart is predominantly muscular, with the muscle termed myocardium. Heart muscle is unique compared to the skeletal muscle of the extremities or the smooth muscle of the digestive system. The special ion channels responsible for the maintenance and transmission of electrical activation are what makes heart muscle so different.

This composite shows how all the various ion channels (Na - sodium; K - Potassium; Ca - calcium e.g.) work over time to make one heart cell activate.

The long "plateau" phase makes the activation more sustained than in skeletal or smooth muscle.
Moreover, each muscle cell in the heart serves a dual purpose - it contracts in response to the activating electrical signals, but then transmits this signals to the cells adjacent to it. The cell provides both contractile function and conductive function.

Proper, organized travel of the electrical signals around the heart leads to the organized contraction of all four chambers and circulation of blood through the heart, lungs and the body. Co-ordinating all of these cells is a dedicated electrical system composed of tissue which initiates and then transmits electrical signaling rapidly throughout the heart. This tissue does not contract like regular myocardium; its only purpose is as an ultrafast electrical "superhighway" spreading electrical activation far and wide.
In normal rhythm, the impulse begins in the *Sinus Node* - a cell cluster at the top of the Right Atrium - which has an automatic firing sequence which can be influenced by many factors such as caffeine, exercise and medications. This impulse travels throughout the atria - the upper chambers of the heart - so that they contract and push blood down, through valves, into the Ventricles - the lower chambers of the heart. The impulse itself travels to the Ventricles through the other major signal control point - the *Atrioventricular Node* - which sits at the midway point between the Atria and the Ventricles.

![Stylized representation of the AV node, plus the Bundle Branches below it](image)

The specialized electrical tissue in the AV Node can be thought of as a filter of sorts, useful in cases where the atrial rhythm becomes abnormal, protecting the ventricles. The AV Node is the other part of the heart's conduction system which is readily affected by medicines, hormones and the body's nervous system. Conduction from the atria via the VA node is not as simple as many would have you believe. The AV Node is actually part of a small series of continuous pathways which "funnel" signals traveling to the Ventricles - the *His Bundle*, and the two *Bundle Branches* (the Right and the Left).

Because everything below the AV Node - His Bundle - Bundle Branch continuity is dependent on it, disease at this level has severe implications for all of the Ventricular activation even if the muscle tissue is health downstream. Permanent Pacemakers are implanted under these circumstances.
All of these components working well together is not some default state to be taken for granted - it is a delicate interplay fundamental to the heart's function and so to life itself. It can all go wrong in 3 basic ways:

1. **Loss of function**

This is the easiest to understand. If the Sinus Node fails to "fire", there is no heartbeat. If the AV Node or His Bundle fails to conduct the impulse to the Ventricles, there is no heart beat. If a Bundle Branch fails, the strength of ventricular contraction is reduced.

![Rhythm strip showing Sinus pause.](image)

2. **Abnormal electrical pathway**

The normal impulse is meant to travel from the top to the bottom of the heart, in one direction, before a brief period of recovery during which time the cells "recharge" and the muscle "relaxes". Some people are born with "extra" wiring; others develop abnormal pathways through age or damage. This now allows the impulse to travel in abnormal directions, creating endless circuits which drive the heart to race.

![Rhythm Strip showing onset of circuit-movement or "re-entry" tachcardia](image)
3. Overactive function

Here, some otherwise passive part of the heart muscle suddenly becomes active and start to "fire" unpredictably, overriding the Sinus node and driving the heart to race or skip. Unlike the Sinus Node, however, this rogue cell is beyond the control of the body’s nervous system.

Rhythm strip show Premature Ventricular Contractions
THE ELECTROPHYSIOLOGY STUDY

Electrophysiology Studies (EPS) are a form of heart catheterization, engaging the heart directly with soft, flexible, plastic-coated electrodes, each placed through an intravenous in the femoral vein as it runs through the crease at the top of the leg.

A running X-ray camera called a Fluoroscope allows the catheter to be visualized as it makes its way from the leg, guided by the Electrophysiologist, following the course of the veins as they make their way to the heart.

Floor-mounted Philips fluoroscope over the head of the table.

Each electrode rests against the inner lining of the heart at key locations, in order to record the heart’s signals and so view the major electrical activation points clearly and directly. By seeing the electrical activation "up close" like this, as opposed to the overlapping fields of the ECG with the lungs and chest wall interposed, a clear diagnosis of the heart rhythm and electrical system can be confirmed.

A 4-electrode and 8-electrode recording catheter.

The multiple signals from the recording catheters during a single normal heartbeat. Unlike a 12-lead ECG, each of these signals is occurring exactly where the catheter is resting inside the heart.

Catheters can be moved to new locations as required during EPS.
But many abnormal heart rhythms come and go randomly. Indeed, most patients who undergo EP Studies present to the EP Lab in normal rhythm. How do we determine their problem on the spot, at EPS?

Here’s where it gets interesting - now that the electrode catheters are in place resting against the inner lining of the heart, very low levels of energy [5 milli-Amperes e.g.] can be run through the catheters to stimulate the heart; in effect to pace it temporarily from key locations and at key timings. This stimulation can induce the abnormal heart rhythm on the spot.

Screenshot of pacing from the atrium which starts off the patient's SVT.

Because the actual energy required to do this is so very slight, the pacing itself cannot be felt by the patient - only the heartbeat is felt.

This arrhythmia induction through programmed stimulation - a series of pacing maneuvers which methodically assess the electrical properties of the atria and ventricles - is the novel, unique aspect of the EP Study which makes it so critically important. Once the abnormal rhythm has been produced, recordings on the electrodes plus further pacing maneuvers can be used to understand its mechanism and the location of abnormal tissue.
CATHETER ABLATION

As useful as EP Study is for diagnostic reasons, the curative aspect provided by Catheter-based Ablation that is unique to all of Cardiology. This is because, although EP Study is occasionally performed to see if a pacemaker is required, the vast majority of EP Study is performed to diagnose abnormally fast heart rhythms in order to cure them outright.

Ablation is the application of either heating or cooling energy to abnormal heart tissue in order to quiet abnormal signals and thereby cure the heart rhythm disorder. After successful ablation, heart rhythm medications are actually discontinued, because the needs to use them has been abolished. Many patients feel better not only because their heart rhythm was cured, but because the side-effects of their medications are gone. After a one-time follow-up visit, patients are discharged from care, sparing them many years of repeat appointments and prescription refills as well.
Ablation catheters are used to heating or cooling energy. Heating energy is provided by *Radiofrequency* catheters. Radiofrequency (RF) energy gets its name from the fact that the electric current used to heat the tissue is at approximately 550 kHz, which is only just below the lower end of the A.M. Radio spectrum, which starts around 570 kHz. These radiowaves locally heat the tissue to abolish abnormal signals. Each application may last as little as 45 seconds and is either painless or feels like a light chest pressure.

![An RF ablation catheter, showing both the tip as well as the handle. Handles have multiple dials, toggles and switches to allow the Electrophysiologist to bend, or deflect, the tip inside the heart with great accuracy and precision in order to target the abnormal signals which must be abolished.](image)

Cooling energy is used in *Cryoablation*, which uses a catheter or, more commonly, a balloon-tipped catheter filled with self-contained nitric oxide that can reach -65C to abolish abnormal signals. Cryoablation is usually reserved for the ablation of Atrial Fibrillation, which targets the four Pulmonary Veins at the back of the Left Atrium. Because each vein is treated all at once by the Cryoballoon, it requires a 3-4 minute cryotherapy application, but is painless.

![Cryoablation ballon catheter with circular recording catheter traveling through it.](image)
**3-DIMENSIONAL MAPPING**

Certain heart rhythm disorders require an additional technique and technology which allows for the recording of thousands of points of information about the heart's anatomy, tissue health and electrical activation in order to understand the abnormal circuit or focus.

In the case of 3-D mapping, catheters are still placed inside the heart to record signals, but now these catheters can be detected and rendered not only by the Fluoroscope as usual, but with impedance patches or magnetic fields on a separate computer system.
3-Dimension Mapping is typically used for certain diagnoses, such as:

- Focal Atrial Tachycardia
- Atypical Atrial Flutter
- Ventricular Tachycardia
- Premature Ventricular Contractions (PVCs)
- Atrial Fibrillation

"Mapping Cases" take longer than Standard cases not necessarily because there is more ablation, but because the data collection (anatomy and electrical activation) is much more involved.
B E F O R E T H E E L E C T R O P H Y S I O L O G Y S T U D Y

Scheduling Your EP Study

All EP studies are scheduled after consultation with an EP Cardiologist, typically with the patient in Clinic or on the hospital ward, but occasionally after referral from a outside Cardiologist from a regional hospital.

The Heart Rhythm Triage Office is responsible for managing all of the referrals from EP Cardiologists' offices, the Trillium Heart Rhythm Clinic, the Trillium Cardiac Device Clinic, the Cardiology wards at Trillium Health Partners Mississauga and Credit Valley sites, the Cardiac Surgery Service, as well as regional hospitals in Peel and York region. In addition to the sheer numbers, each patient referral has a level of acuity: elective, urgent and emergent. Sometimes, patient status can change from week to week or day to day.

Balancing all of these competing priorities in dynamic health care environment may lead to your case being rescheduled, sometimes at the last minute, and occasionally more than once. We regret the inconvenience which this produces for you and thank you in advance for your understanding if this situation arises.

For outpatients, the Heart Rhythm Triage Office will call you at home in the months before your potential scheduled time to ensure that it is convenient, plus to allow you to make arrangements for work and travel, for example. You will also be called in the days prior to your procedure to confirm the date and arrival time.
PREPARING FOR YOUR EP STUDY

These are general guidelines to follow in preparation for your EPS. You may receive more specific instructions from your EP Cardiologist.

- an information package will be mailed to you, which will include directions, instructions and a requisition for some basic blood tests.

- shower or bathe the evening before or the morning of your procedure.

- you must be fasting for your EP Study, however, some medications may be permitted with a sip of water on the morning of your case. Otherwise you must take nothing by mouth after midnight on the day of your procedure.

- heart rhythm medications may be continued right up to your procedure, or they may be stopped several days beforehand. Your EP Cardiologist will provide specific instructions which the Triage Office will remind you when they call you to confirm your case day and time.

- blood thinners - also known as anticoagulants - require special consideration. Many are continued throughout the procedure; some will require blood tests beforehand and on the day of the procedure. Your EP Cardiologist will make this decision and the Heart Rhythm Triage Office will remind you when they call.

- you should try to arrange for someone else to drive you to and from the hospital, since you cannot drive yourself home safely after receiving sedation during the procedure.
**AT THE HOSPITAL**

Once your have registered, you will proceed to the Cardiac Catheterization Laboratory where the Nursing Staff will check you in and prepare you for the EP Study.

This preparation includes:

- changing into a hospital gown

- recording blood pressure, heart rate, oxygen levels and ECG

- clipping the hair on the chest and groin and placing numbing cream on the groin site.

- sending blood tests, if required

- starting one, or two, intravenous lines in the arms

- review of pre-operative blood test results

- review of medical history, surgical history and allergies

- confirmation of fasting state and medications which were taken or held.
**During Your EP Study**

Every EP Study is different, quite literally. Different numbers and sizes of IV in the legs; different diagnostic catheters; different pacing maneuvers; different ablation strategies. Although there the approach, overall, is standardized depending on the rhythm category under investigation, because each patient is unique there are always adjustments made as the case progresses. Your Electrophysiologist will be in the EP Lab with you, performing the procedure and directing all aspects of your care. Sometimes, there will be an opportunity to explain how things are going and what has been found. At all times, there is an EP nurse in the Lab attending to patient comfort and safety.

![A typical set of cable connections for a Standard EP Study.](image)

Once in the EP Lab, however, some things remain the same:
- nursing staff will place monitoring electrodes on the chest, larger cardioversion pads as well, plus oxygen and blood pressure monitoring equipment.
- the leg site where the IVs and catheters will travel is carefully scrubbed with special soap and the entire body draped in a sterile blanket.
- intravenous sedation will be given for relaxation and comfort. The amount used differs in every case, as some heart rhythm disorders require patient wakefulness and even IV adrenaline to initiate them. General Anaesthesia, which requires mechanical ventilation, is rarely ever used. Local anaesthetic is used on the leg sites where the numbing cream had been and where the IVs will go.
AFTER YOUR EP STUDY

In the Recovery Area / Short-Stay Unit

The catheters are removed in the EP Lab, but the large IVs in the leg veins are removed in Recovery/Short-Stay. If blood thinners were used during the case, these must be reversed before the IVs can be removed. Nursing staff will remove the IVs, hold pressure over the site and then place a Band-Aid™ in place. You will need 2-4 hours of bed rest after this, with the legs held still to allow the puncture sites to heal.

Once the IVs are removed, you may eat and drink again. Once bed-rest has finished, the nursing staff will help you up and ensure you can walk around. They will monitor the leg sites carefully as you begin to move about. Then you can go home or back to your hospital room.

At Home

For 3-5 days, depending on the case, you must avoid straining, squatting, heavy lifting or walking. Walking moderately is recommended. Avoid driving or travel in the first 5 days. Keep the leg site dry for 48 hours, then shower as usual and remove the Band-Aid™. You may return to work after 3 days of recovery as well.

Feeling an occasional, brief "skip" or the feeling "like the arrhythmia is going to start" is normal and expected. Mild discomfort, slight bruising or small bump under the skin - which fades away over time - are normal.
When To Call Your Doctor

1. If chest pain persists or worsens after the procedure
2. If shortness of breath develops
3. If the leg site bleeds, becomes swollen or increasingly reddened.
4. If your abnormal heart rhythm recurs.

Discharge Instructions

In many cases, medications will be stopped after your EP Study and ablation. In some cases, however, medications are continued for a short while after the procedure. Blood thinners may be used for a few months after certain complex ablations. You will be given a printed handout detailing your precise medication regimen, any testing to be done, and follow-up scheduling. (see next page for example).
Take Original (white copy) to community pharmacist
Your home medications have been compared to your hospital medications

<table>
<thead>
<tr>
<th>DATE:</th>
<th>DISCHARGE:</th>
<th>Diagnostic Tests:</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROCEDURE:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>24-hour Holter</td>
</tr>
<tr>
<td>FOLLOW-UP APPOINTMENTS:</td>
<td>48-hour Holter</td>
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<tr>
<td></td>
<td></td>
<td>2-week Spiderflash™</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4-week Spiderflash™</td>
</tr>
</tbody>
</table>

- Cardiac Device Clinic as per Clinic Appointment Sheet
- Electrophysiologist _____ week(s) (Patient to call to make appointment)
- Monitor to be arranged now for placement in _____ week(s)

SECTION A: The Following medications are new or changed from your home medications

<table>
<thead>
<tr>
<th>New or Changed</th>
<th>Medications and Instructions</th>
<th>Quantity</th>
<th>Repeat</th>
<th>LU#</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- □ Prescription(s) for _____________________________ may have been provided to you but not listed above

SECTION B: The following medications are to be continued according to home medications

<table>
<thead>
<tr>
<th>Continue</th>
<th>Pradaxa to restart</th>
<th>Eliquis to restart</th>
<th>Xarelto to restart</th>
<th>Warfarin to restart</th>
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</thead>
</table>

SECTION C: The following home medications are to be held or stopped

<table>
<thead>
<tr>
<th>Stop</th>
<th>Credit Valley Hospital</th>
<th>Mississauga Hospital</th>
<th>Queensway Health Centre</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2200 Eglinton Avenue West</td>
<td>100 Queensway West</td>
<td>150 Sherway Drive</td>
</tr>
<tr>
<td></td>
<td>Mississauga ON L5M 2N1</td>
<td>Mississauga ON L5B 1B8</td>
<td>Toronto ON M9C 1A5</td>
</tr>
<tr>
<td></td>
<td>T: (905) 813-2200</td>
<td>T: (905) 848-7100</td>
<td>T: (416) 259-6671</td>
</tr>
</tbody>
</table>

Note: Medications without quantity is not a prescription but for information only

- All future refills to go through the patient’s family doctor
- Prescriber’s Name: _____________________________ Signature: _____________________________
- Date: _______________________________________
- CPSO-License #: ____________________________ (CPSO# required for narcotic and controlled Rx)

White: Community Pharmacy  Yellow: Health Record  Pink: Family Doctor
DONATION FORM

The Trillium Heart Rhythm Service appreciates all donations. Donations are used to purchase equipment which allows our EP Lab to remain among the most advanced in Canada.

Name: ___________________________
Phone: ___________________________
Email: ___________________________
Address: ___________________________

City: _____________________________ Postal Code: ____________

Donation:
☐ I would like make a credit card donation (please call me)
☐ I have enclosed a donation cheque

Please direct my donation to:
☐ Cardiac Device Clinic
☐ Cardiac Electrophysiology Laboratory
☐ Trillium Health Centre Foundation area of greatest need

Please email, fax or mail this form along with your donation to:

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Trillium Health Centre
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Mississauga L5B 1B8
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F: 905.804.7927