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ONTARIO HEALTH TECHNOLOGY ASSESSMENT SERIES

Long-Term Continuous Ambulatory ECG Monitors and External Cardiac Loop Recorders for Cardiac Arrhythmia: A Health Technology Assessment

KEY MESSAGES

Cardiac arrhythmia is a group of conditions in which the heart is beating too fast, too slow, or erratically. Symptoms of arrhythmia may include chest pain, fainting, dizziness, or a racing or thumping heart. To diagnose an arrhythmia, doctors often use an electrocardiograph (ECG). For patients whose symptoms occur too infrequently to be detected by an ECG, doctors frequently ask them to use a device called an ambulatory ECG monitor (often called a Holter monitor). The patient wears the device at home to record their heart's electrical signals while they are ambulatory (walking around), doing normal activities.

For many years, the standard devices used for this test were able to store data for up to 24 or 48 hours. Patients who needed monitoring beyond 48 hours could use a device known as an *external cardiac loop recorder*. But due to their limited data storage capacity, these devices automatically erase normal signals after a few minutes and only keep the abnormal signals. Newer devices, known as *long-term continuous ambulatory ECG monitors*, with more data storage capacity are now available. Their use in Ontario has grown steadily since they became publicly funded in 2006—and particularly since 2011, when funding was extended to models that can record for two weeks or longer. At the same time, the use of external cardiac loop recorders has decreased.

This health technology assessment looked at the effectiveness and costs of long-term continuous ECG monitors, compared with loop recorders. In our review of published research, we found that the two types of devices were equally effective in their ability to detect symptomatic cardiac arrhythmias. Assuming that the use of long-term continuous ECG monitors continues to grow in Ontario, we estimated that the added costs to the province's health care system would be between $130,000 and $370,000 per year for the next 5 years. However, this estimate relies on several assumptions, including that there will be no change in the fees associated with the use of each test.

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ABSTRACT

Background

Ambulatory electrocardiography (ECG) monitors are often used to detect cardiac arrhythmia. For patients with symptoms, an external cardiac loop recorder will often be recommended. The improved recording capacity of newer Holter monitors and similar devices, collectively known as long-term continuous ambulatory ECG monitors, suggests that they will perform just as well as, or better than, external loop recorders. This health technology assessment aimed to evaluate the effectiveness, cost-effectiveness, and budget impact of long-term continuous ECG monitors compared with external loop recorders in detecting symptoms of cardiac arrhythmia.

Methods

Based on our systematic search for studies published up to January 15, 2016, we did not identify any studies directly comparing the clinical effectiveness of long-term continuous ECG monitors and external loop recorders. Therefore, we conducted an indirect comparison, using a 24-hour Holter monitor as a common comparator. We used a meta-regression model to control for bias due to variation in device-wearing time and baseline syncope rate across studies. We conducted a similar systematic search for cost-utility and cost-effectiveness studies comparing the two types of devices; none were found. Finally, we used historical claims data (2006–2014) to estimate the future 5-year budget impact in Ontario, Canada, of continued public funding for both types of long-term ambulatory ECG monitors.

Results

Our clinical literature search yielded 7,815 non-duplicate citations, of which 12 cohort studies were eligible for indirect comparison. Seven studies assessed the effectiveness of long-term continuous monitors and five assessed external loop recorders. Both types of devices were more effective than a 24-hour Holter monitor, and we found no substantial difference between them in their ability to detect symptoms (risk difference 0.01; 95% confidence interval –0.18, 0.20). Using GRADE for network meta-analysis, we evaluated the quality of the evidence as low.

Our budget impact analysis showed that use of the long-term continuous monitors has grown steadily in Ontario since they became publicly funded in 2006, particularly since 2011 when monitors that can record for 14 days or longer became funded, and the use of external cardiac loop recorders has correspondingly declined. The analysis suggests that, with these trends, continued public funding of both types of long-term ambulatory ECG testing will result in additional costs ranging from $130,000 to $370,000 per year over the next 5 years.

Conclusions

Although both long-term continuous ambulatory ECG monitors and external cardiac loop recorders were more effective than a 24-hour Holter monitor in detecting symptoms of cardiac arrhythmia, we found no evidence to suggest that these two devices differ in effectiveness. Assuming that the use of long-term continuous monitors will continue to increase in the next 5 years, the public health care system in Ontario can expect to see added costs of $130,000 to $370,000 per year.

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BACKGROUND

Health Condition

Cardiac arrhythmia, or abnormal heartbeat, is a group of conditions in which the heart beats too fast, too slowly, or erratically.[1] Symptoms of arrhythmia (also called dysrhythmia) include chest pain, fainting, dizziness, and a racing or thumping heartbeat.

Clinical Need and Target Population

Many arrhythmias can increase the risk of stroke, heart attack, heart failure, or sudden cardiac death (which kills 40,000 Canadians a years).[2] Atrial fibrillation is the most common serious arrhythmia and affects about 2% to 3% of people in North America and Europe.[3]

Technology

Ambulatory electrocardiography (ECG) monitors are devices that patients with suspected arrhythmia use at home to record their heart's electrical activity while they are walking around (are ambulatory) and doing normal activities. These monitors are useful for assessing patients who have intermittent arrhythmias that may not be detected by an ECG test in the hospital. Ambulatory monitors can also help to predict a patient's risk of developing arrhythmia, monitor a patient's response to treatment for arrhythmia, and evaluate silent ischemia (loss of blood flow or oxygen to the heart without the typical chest pain).

Most ambulatory ECG monitors consist of small electrodes placed with adhesive to the patient's chest, with wires connecting them to a small recorder attached to a belt. The patient also receives a diary to note the time when symptoms develop. When data from the monitor are analyzed, any abnormal heart rhythms that overlap with recorded symptoms can help the doctor understand whether an arrhythmia may account for the symptoms and what type of arrhythmia the patient is experiencing.

There are three categories of ambulatory ECG monitors:

- *Continuous monitors* store the heart's electrical signals for the entire time the patient wears the device. Continuous monitors have two types:
    - *Short term,* known as *24- or 48-hour Holter monitors*
    - *Long term,* which can record for more than 48 hours. In recent years, new technology has allowed ambulatory ECG monitors to have more memory while still being small and lightweight; these are known as *efficient-memory Holter monitors* and *patch monitors* (designed without the wires connecting electrodes to the recorder)
- *Intermittent long-term monitors* store the heart's electrical signals only when the monitor is triggered by a patient or by abnormal heart rhythm. These monitors also have two types:
    - *Event monitors*, also known as post-event recorders, which typically store 5 to 7 minutes worth of data from the moment triggered
    - *Cardiac loop recorders*, which continuously record new signals, erase old signals, and lock in data when triggered. They typically store 1 to 4 minutes worth of data. Loop recorders can be either *external*, worn around the waist or wrist, or *insertable* (also known as *implantable*), implanted under the skin in the left parasternal region (near the heart)

- *Real-time cardiac telemetry systems*, also known as *mobile cardiac outpatient telemetry*, are similar to long-term continuous monitors but can send the data directly to a central monitoring station instead of recording it to be downloaded later

In the past, doctors often recommended an external cardiac loop recorder for patients who needed to monitor their symptoms for more than 48 hours. However, the larger memory in the newer long-term continuous ambulatory ECG monitors suggests that they will perform just as well as, or better than, external loop recorders. The aim of this review, requested by the Ontario Ministry of Health and Long-Term Care, was to evaluate whether long-term continuous ECG monitors are equally or more effective compared with external cardiac loop recorders in diagnosing patients with symptomatic cardiac arrhythmia.

Regulatory Information

We identified 130 brands of short-term and long-term Holter monitors, four brands of external loop recorders, and one brand of patch monitor that have been licensed by Health Canada.

Context

Services for both long-term continuous ambulatory ECG monitors and external cardiac loop recorders are publicly funded in Ontario and other provinces in Canada. In Ontario there are separate fee codes for types of ambulatory ECG monitors. Fee codes for continuous ECG monitors are broadly categorized according to whether the devices can record the entire portion of the monitoring period and provide trend analysis, for a minimum of 12 hours recording. Fee codes for external cardiac loop recorders are fixed and applies to devices that are used continuously for 14 days. Fee codes are also fixed for event monitors although the duration of use is not specified.

The combined volume of Ontario Health Insurance claims in 2014 for use of long-term continuous ambulatory ECG monitors and external cardiac loop recorders for cardiac arrhythmia was 85,000. Claims for long-term continuous ambulatory ECG monitors increased from 638 in 2006 to 37,191 in 2014. In the same period, claims for external cardiac loop recorders increased from 20,398 to 47,437.

Research Questions

- Is a long-term continuous ambulatory ECG monitor equally or more effective than an external cardiac loop recorder in detecting symptomatic cardiac arrhythmias?
- What is the cost-effectiveness of long-term continuous ambulatory ECG monitors compared with external cardiac loop recorders for the diagnosis of cardiac arrhythmias in patients with intermittent symptoms?
- What is the budget impact, within the context of the Ontario Ministry of Health and Long-Term Care, of continuing to publicly fund long-term continuous ambulatory ECG monitors compared with external cardiac loop recorders for the diagnosis of symptomatic cardiac arrhythmias?

CLINICAL EVIDENCE REVIEW

Objective

The objective of this review was to evaluate the effectiveness of long-term continuous ambulatory electrocardiography (ECG) monitors compared with cardiac loop recorders in detecting symptoms of cardiac arrhythmia.

Methods

Sources

We performed a literature search on January 15, 2016, using All Ovid MEDLINE, Embase, Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, Centre for Reviews and Dissemination Health Technology Assessment Database, Cochrane Central Register of Controlled Trials, and National Health Service Economic Evaluation Database, for studies published any period before January 15, 2016. Search strategies were developed by medical librarians using medical subject headings (MeSH). The final search strategy was peer-reviewed using the PRESS Checklist.[4] See Appendix 1 for full details, including all search terms.

Literature Screening

A single reviewer screened the abstracts and, for those studies meeting eligibility criteria, we obtained full-text articles. We also examined reference lists for any additional relevant studies not identified through the search.

Inclusion Criteria

- English-language full-text publications
- Studies published up to January 15, 2016
- Randomized controlled trials, cohort studies
- Studies including long-term continuous ambulatory ECG monitors or external cardiac loop recorders as a detection device

Exclusion Criteria

- Editorials, case reports, or commentaries

Outcomes of Interest

- Arrhythmias detected by an ambulatory ECG device and correlated with the following symptoms: paroxysmal (intermittent) atrial fibrillation and flutter, presyncope (light-headedness), syncope (fainting), and palpitations (racing or thumping heart)

Data Extraction

We extracted relevant data on study characteristics including citation information, study design, inclusion criteria, details on the device, and outcomes.

Statistical Analysis

Because we did not identify any studies that directly compared a long-term continuous monitor with an external loop recorder, we performed an indirect assessment using other classes of ambulatory ECG devices as a common comparator. After screening articles, we found that only 24-hour Holter monitors were evaluated against both types of long-term monitors; therefore, we used 24-hour Holter monitors as the common comparator for our analysis.

Our preliminary indirect comparison analysis did not account for intransitivity bias (bias arising from mixing studies with different characteristics). In subsequent analysis, we accounted for this bias through a meta-regression model that adjusted for the time that patients wore the device and their baseline syncope rate. We fitted a weighted least square meta-regression model, where each study was weighted by the inverse of its variance. The model is summarized below:

$$RD_H = \beta_0 + \beta_1 * Time + \beta_2 * SyncopeComparator + \beta_3 * SyncopeIntervention + \beta_4 * Intervention,$$

where $Time$ is the duration of wearing the device, $SyncopeComparator$ is the reported percentage of patients with baseline syncope in the 24-hour Holter monitor group, $SyncopeIntervention$ is the reported percentage of patients with baseline syncope in either device group, $Intervention$ is an indicator variable for the type of device (1 = long-term continuous monitor, 0 = external loop recorder), the parameters β_0 to β_4 are regression coefficients, and RD_H is the study-specific risk difference comparing $Intervention$ with 24-hour Holter monitor in detecting symptoms of cardiac arrhythmia.

The quantity β_4 can be interpreted as an estimate of indirect risk difference (RD) for detecting arrhythmia between the two types of devices, when holding constant the device-wearing time and baseline syncope rate across all studies.

We tested for significance of time-intervention interaction by including this term in a meta-regression model. We had planned to control for the time lag between hospital discharge and initiation of intervention, but this information was not reported consistently across studies so our analysis does not account for time-lag variation between studies. We did not perform an analysis by type of arrhythmia due to the small number of studies.

Moreover, we did not correct standard errors to account for repeated measurements, as this would require access to patient-level data. For this reason, the reported 95% confidence intervals (CIs) are conservative; that is, the intervals do not provide optimal bounds for random errors. All analyses were done in R version 3.0.2. Appendix 2 provides more detail on our statistical methods.

Quality of Evidence

The quality of the body of evidence for each outcome was examined according to the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) Working Group criteria for network meta-analysis.[5] The overall quality was determined to be high, moderate, low, or very low using a step-wise, structural methodology (Appendix 3).

Expert Consultation

On January 2016, we solicited expert consultation on the use of ambulatory ECG monitors from physicians specialized in cardiology and electrophysiology. The role of the expert advisors was to contextualize the evidence and provide advice on the clinical importance of various ambulatory ECG devices. We also consulted them in developing the research question, and they reviewed an earlier draft of this report. However, the statements, conclusions, and views expressed in the report do not necessarily represent the views of the consulted experts.

Results

Literature Search

The database search yielded 11,121 citations published between January 1, 1983, (the earliest date in any of the collections) and January 1, 2016. After removing duplicates, we reviewed titles and abstracts to identify relevant articles. We obtained the full texts of these articles for further assessment. Ten articles met the inclusion criteria; two of these articles reported different estimates for groups by device or population, so in each case we considered these as two separate studies, for a total of 12 included studies. We hand-searched the reference lists of the included studies, along with health technology assessment websites and other sources, to identify additional relevant studies.

Figure 1 presents the flow diagram for the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA).

Included Studies

The 12 included studies were of mixed designs, including cohort designs with independent groups where each group received separate devices (n = 3), cohort designs with pre-post measurements where each individual wore each device type sequentially (n = 5), and cohort studies with simultaneous measurements where each individual wore both devices at once (n = 4). Seven of the studies compared a long-term continuous monitor with a 24-hour Holter monitor, and five compared an external loop recorder with a 24-hour Holter (Table 1). Figure 2 depicts the indirect comparison that we performed.

Methodological Quality of the Included Studies

The risk of bias assessment for included studies is summarized in Appendix 3, Table A1. All 12 studies were deemed directly applicable to the research question. We assessed the methodological quality of these studies and determined that three of them had some limitations.

Methodological Quality of Indirect Assessment

Since no study directly compared long-term continuous monitors and external loop recorders, we downgraded the quality of evidence based on indirectness. We also downgraded based on imprecision and potential for confounding (Table 2).

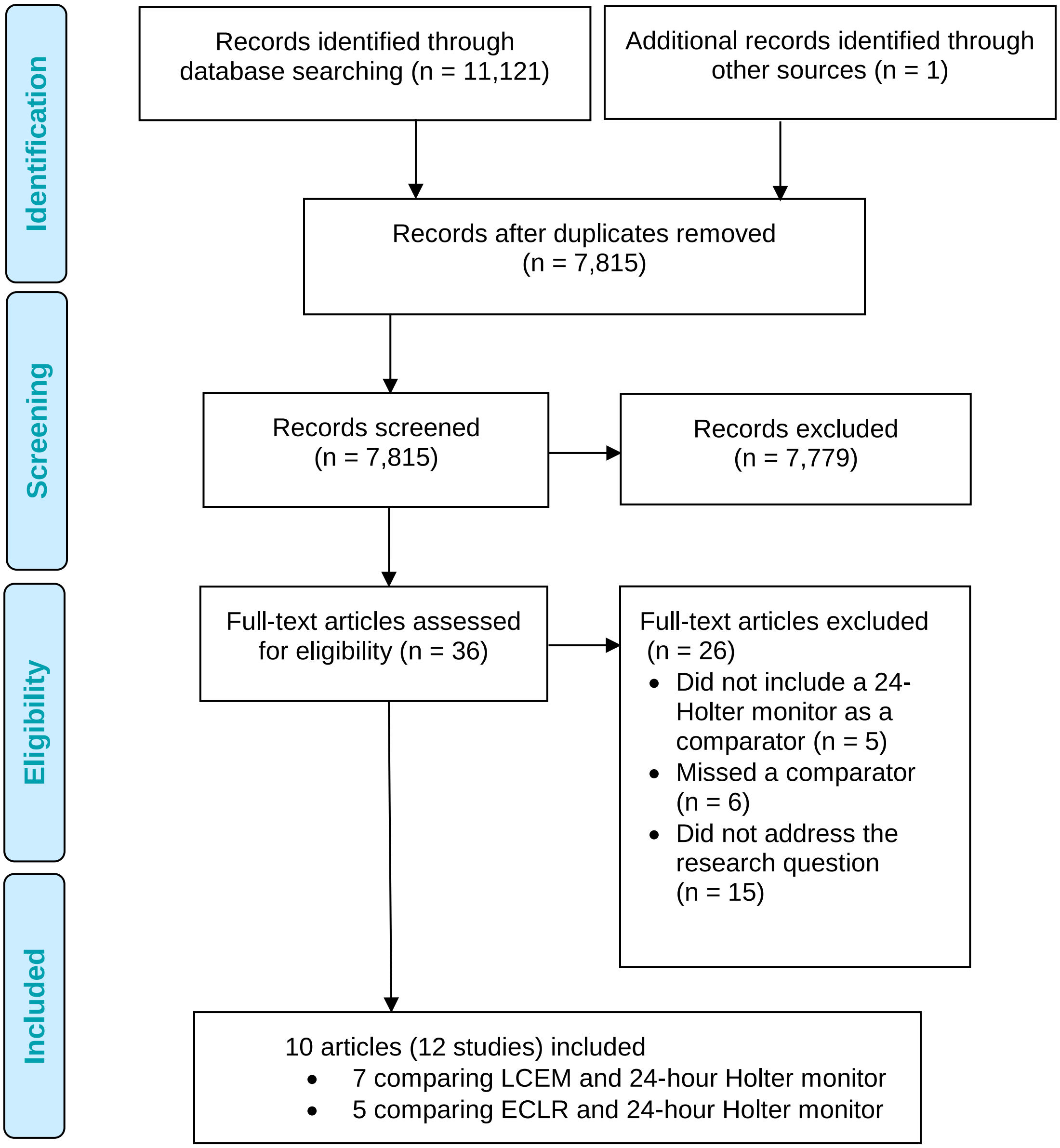

Figure 1: PRISMA Flow Diagram for the Clinical Evidence Review

Abbreviations: ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory electrocardiography monitor
Source: Adapted from Moher et al.[6]

Table 1: Characteristics of Included Studies

Author, Year	Country	Design	Total Observations, N	Indication	Intervention			Comparator (24-Hour Holter)	
					Type[a]	Events, n	Observations, n	Events, n	Observations, n
Studies of long-term continuous ambulatory ECG monitors									
Barrett et al, 2003[7]	United States	Cohort (wearing both devices simultaneously)	292	Palpitations, syncope, dizziness	14-day LCEM	41	146	27	146
Manina et al, 2012[8]	Italy	Cohort (wearing both devices sequentially)	111	Cryptogenic ischemic stroke	4-day LCEM	29	111	0	111
Pastor-Pérez et al, 2010 (1)[9]	Spain	Cohort (wearing both devices simultaneously)	74	Stable CHF, non-ischemic stroke	7-day LCEM	20	37	13	37
Pastor-Pérez et al, 2010 (2)[9]	Spain	Cohort (wearing both devices simultaneously)	52	Stable CHF, ischemic stroke	7-day LCEM	12	26	3	26
Ritter et al, 2013[10]	Germany	Cohort (wearing both devices sequentially)	120	Cryptogenic stroke	7-day LCEM	1	60	0	60
Scherr et al, 2008[11]	Austria	Cohort (wearing both devices sequentially)	36	Palpitations	30-day LCEM	13	18	0	18
Stahrenberg et al, 2010[12]	Germany	Cohort (wearing both devices simultaneously)	448	Cerebral ischemia	7-day LCEM	28	224	15	224
Studies of external cardiac loop recorders									
Jabaudon et al, 2004[13]	Switzerland	Cohort (wearing both devices sequentially)	176	Stroke, TIA	7-day ECLR	5	88	0	88

Author, Year	Country	Design	Total Observations, N	Indication	Intervention: Type[a]	Intervention: Events, n	Intervention: Observations, n	Comparator (24-Hour Holter): Events, n	Comparator (24-Hour Holter): Observations, n
Locati et al, 2013[14]	Italy	Cohort	184	Syncope	30-day ELR	16	92	0	92
Mlynarczyk et al, 2015[15]	Poland	Cohort (wearing both devices sequentially)	96	Palpitations	3- to 10-day ECLR	33	48	24	48
Reiffel et al, 2005 (1)[16]	United States	Cohort	1,800	Known or suspected dysrhythmias	30-day ECLR (patient-triggered	204	600	37	600
Reiffel et al, 2005 (2)[16]	United States	Cohort	1,800	Known or suspected dysrhythmias	30-day ECLR (auto-triggered	268	600	37	600

Abbreviations: CHF, congestive heart failure; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory electrocardiography monitor; TIA, transient ischemic attack.
[a]In our meta-regression model, the value for time was extracted from this column.

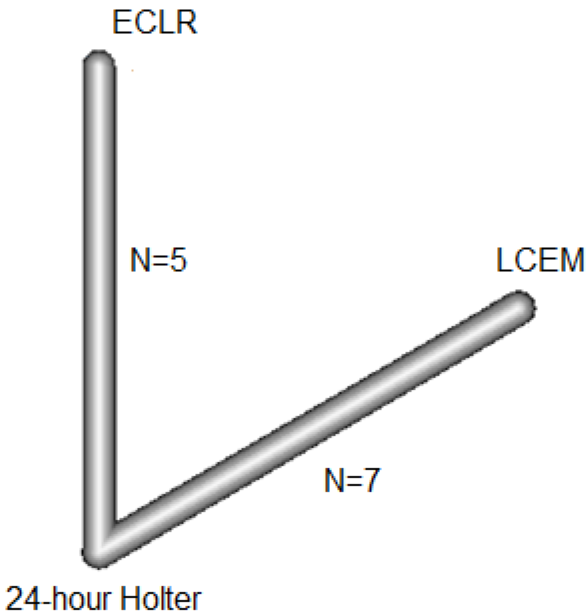

Figure 2: Network Graph Depicting the Indirect Comparison of Long-Term Ambulatory ECG Monitors

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor; N, number of studies.

Table 2: GRADE Table for Rating the Quality of Evidence

Comparison	Direct Evidence		Indirect Evidence[a,b]	
LCEM vs. ECLR	**RD (95% CI)**	**Quality of evidence**	**RD (95% CI)**	**Quality of evidence**
	Not available	Not applicable	0.01 (–0.18, 0.20)	Low[c]

Abbreviations: CI, confidence interval; ECLR, external cardiac loop recorder; GRADE, Grading of Recommendations Assessment, Development, and Evaluation; LCEM, long-term continuous ambulatory electrocardiography monitor; RD, risk difference.
[a]Reported results are for meta-regression.
[b]Indirect evidence in this case is synonymous to network meta-analysis results
[c]Downgraded for indirectness, precision, and confounding.

Results of Statistical Analysis

In the unadjusted analysis, we did not find a notable difference between long-term continuous monitors and external loop recorders in their effectiveness to detect symptomatic arrhythmias (RD 0.03, 95% CI −0.12, 0.19) (Figure 3). Results remained robust after accounting for intransitivity bias (RD 0.01; 95% CI −0.18, 0.20) (Table 2). Both devices were more effective than a 24-hour Holter monitor in detecting symptomatic arrhythmias (Figure 3).The statistical test for time-intervention interaction was not significant (*P* = 0.648).

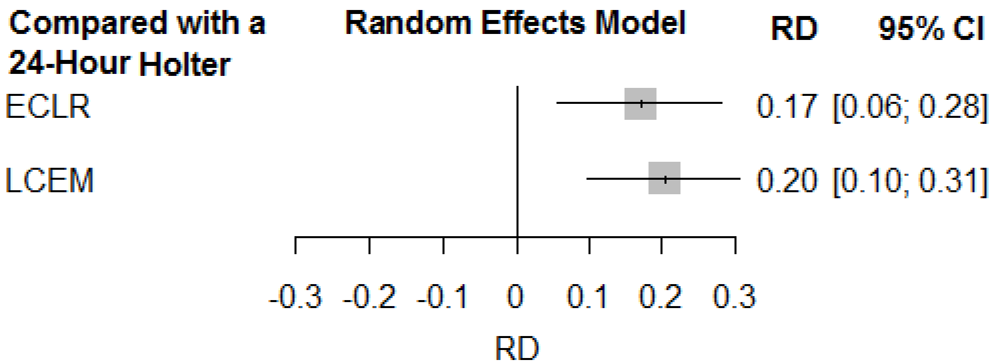

Figure 3: Forest Plot of Pooled Comparison of Long-Term Ambulatory ECG Monitors

Abbreviations: CI, confidence interval; ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory electrocardiography monitor; RD, risk difference.

Discussion

We did not find a discernible difference between long-term continuous ambulatory ECG monitors and external cardiac loop recorders in detecting intermittent symptomatic arrhythmias. Both types of devices were more effective than a 24-hour Holter monitor.

These findings are in line with the recommendation of the Canadian Agency for Drugs and Technologies in Health, which advises that either device can be used to monitor cardiac function for patients who have been discharged from hospital following an ischemic stroke or transient ischemic attack.[17] Our review involved a broader population, including patients with history of palpitations, presyncope, syncope, and paroxysmal atrial fibrillation.

Our findings are also consistent with the recently published EMBRACE trial (30-Day Cardiac Event Monitor Belt for Recording Atrial Fibrillation After a Cerebral Ischemic Event). That study demonstrated substantial benefits of a 30-day event-triggered external loop recorder compared with a short-term Holter monitor in detecting arrhythmias among stroke patients in Canada with suspected atrial fibrillation.[18]

We note the following limitations in our review. First, we were unable to identify studies that directly compared long-term continuous monitors and external loop recorders. To address this problem, we applied the indirect comparison approach, accounting for factors that could explain differences between studies. However, our analysis was not able to account for factors such as variation between studies in the time lag from hospital discharge to the start of the intervention, leaving room for residual bias. Second, two studies (reported in the same article)[16] did not account for any potential confounding, suggesting that their findings are prone to bias. Finally, imprecision in summary estimates limited our ability to make a firm conclusion on results. For these reasons we ranked the quality of evidence as low.

Our review focused on detecting intermittent, symptomatic arrhythmia. However, in instances where the interest is in gathering more detailed information on arrhythmias—for example, examining days or weeks worth of data to determine the most effective regimen to treat arrhythmia—a long-term continuous monitor might be preferable to an external loop recorder. Such assessment is beyond the scope of this review.

Conclusion

The available evidence does not suggest that long-term continuous ambulatory ECG monitors and external cardiac loop recorders differ in their effectiveness to detect symptomatic arrhythmia.

ECONOMIC EVIDENCE REVIEW

Objectives

The objective of this study was to review the published literature on the cost-effectiveness of long-term continuous ambulatory electrocardiography (ECG) monitors compared with external cardiac loop recorders in patients with intermittent symptoms of cardiac arrhythmia.

Methods

Sources

We performed an economic literature search on January 27, 2016, updating it until May 20, 2016, using Ovid MEDLINE, Ovid MEDLINE In-Process, Ovid Embase, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, Centre for Reviews and Dissemination Health Technology Assessment Database, and National Health Service Economic Evaluation Database, for studies published from January 1, 2006, to May 20, 2016. We also reviewed reference lists of included economic literature and the website of the Canadian Agency for Drugs and Technologies in Health for any additional relevant studies not identified through the systematic search. The final search strategy was peer-reviewed using the PRESS Checklist.[4] See Appendix 1 for full details, including all search terms.

Literature Screening

We based our search terms on those used in the clinical evidence review of this report and applied economic filters to the search results. A single reviewer reviewed titles and abstracts and, for those studies meeting the inclusion and exclusion criteria, we obtained full-text articles.

Inclusion Criteria

- English-language full-text publications
- Studies published between January 1, 2006, and May 20, 2016
- Studies reporting on the long-term continuous ambulatory ECG monitor compared with the external cardiac loop recorder as a diagnostic device for arrhythmia
- Studies of patients at any age with intermittent symptoms of arrhythmia
- Cost-utility or cost-effectiveness analyses in any country
- Any type of economic analysis in Canada (i.e., cost-utility analyses, cost-effectiveness analyses, cost-benefit analyses, budget impact analyses, or cost analyses)

Exclusion Criteria

- Abstracts, letters, editorials, narrative reviews, commentaries, unpublished studies
- Foreign-language publications

Outcomes of Interest

- Costs, cost per quality-adjusted life-year (QALY), cost per clinical effect

Data Extraction

We extracted relevant data on the following:

- source (i.e., name, location, year)
- population and comparator
- interventions
- outcomes (i.e., health outcomes, costs, cost-effectiveness)

Study Applicability Appraisal

We determined the usefulness of each included study by applying a modified methodology checklist for economic evaluations developed by the National Institute for Health and Care Excellence (NICE) in the United Kingdom. The original checklist is used to inform development of clinical guidelines by NICE.[19] An example of the modified methodology checklist can be found in Appendix 4. We modified the wording of the questions to remove references to guidelines and to make it Ontario specific. The original NICE checklist was separated into two sections: an applicability section and a methodological quality section. We used only the first section for our review. From this checklist, studies are deemed directly applicable, partially applicable, or not applicable to the research question.

Limitations

The literature review was limited to a single reviewer.

Results

Literature Search

The database search yielded 336 citations published between January 1, 2006, and May 20, 2016 (with duplicates removed). An additional five articles were obtained from other sources. We excluded a total of 272 articles based on information in the title and abstract. We then obtained the full texts of 69 potentially relevant articles for further assessment. Figure 4 presents the flow diagram for the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA).

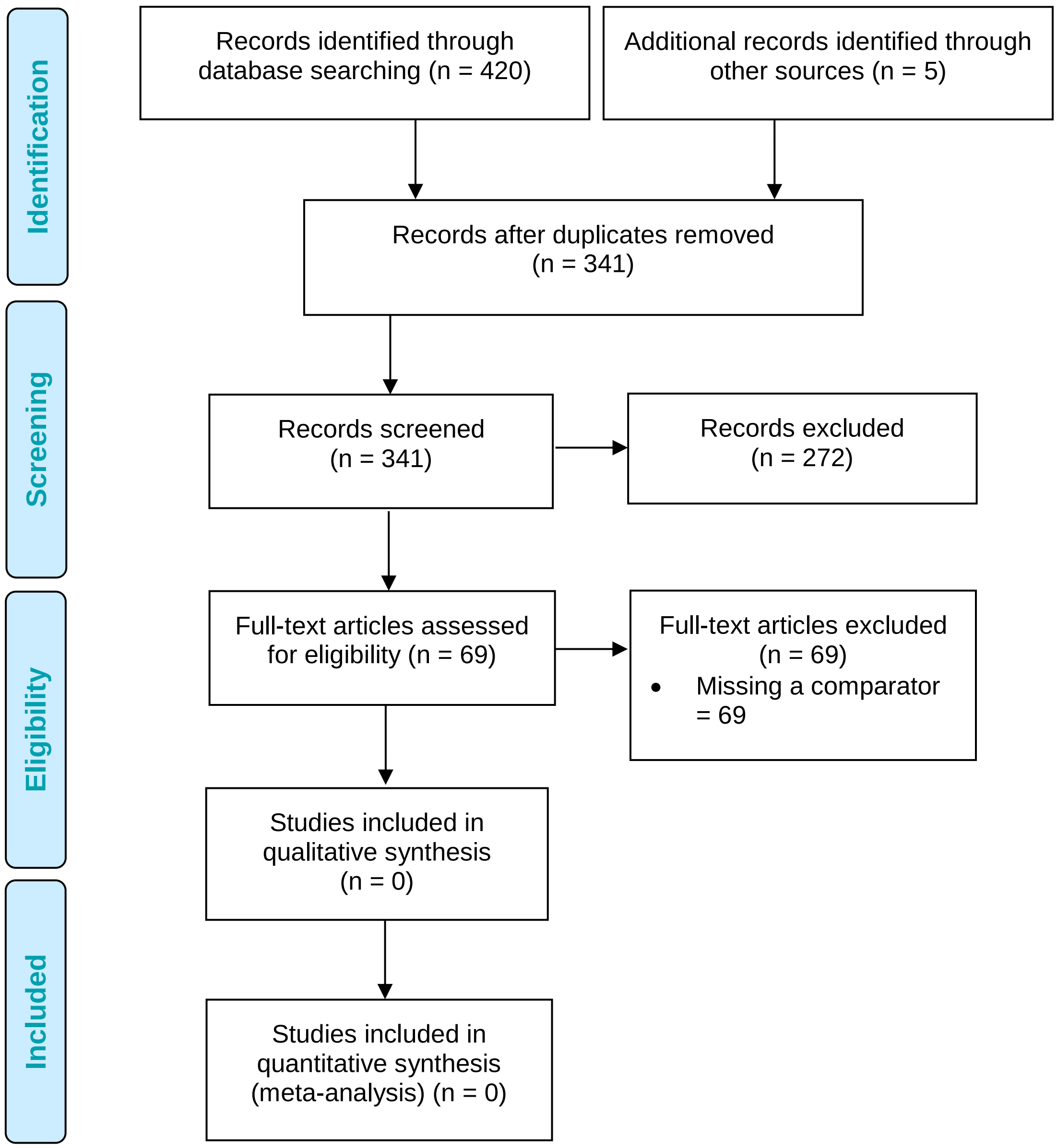

Figure 4: PRISMA Flow Diagram for the Economic Evidence Review

Source: Adapted from Moher et al.[6]

We found no studies that directly compared the cost-effectiveness of long-term continuous ambulatory ECG monitors and external cardiac loop recorders in patients with intermittent symptoms of cardiac arrhythmia. Thus, all studies were excluded from our review.

Discussion

While no studies directly compared the cost-effectiveness of the long-term continuous ECG monitor and the external cardiac loop recorder, we identified two Canadian studies that evaluated the cost-effectiveness of external loop recorders for ambulatory ECG monitoring compared with continuous short-term recorders and/or no screening.[20-22] One study, piggy-backed onto an Ontario prospective randomized trial, found that the external loop recorder had an incremental cost-effectiveness ratio (ICER) of $1,096 per extra successful diagnosis of correlation between symptoms and arrhythmia, compared with the 48-hour Holter monitor, in patients with syncope or presyncope.[21,22] In addition, a recent health technology assessment evaluated the 7-day and 30-day external cardiac loop recorders against the 24-hour Holter device and no screening to detect atrial fibrillation.[20] In a population of patients with recent ischemic stroke or transient ischemic attack, the ICERs ranged from $50,000 to $85,000 per QALY.[20] These findings highlight the potential cost-effectiveness of the external loop recorder and/or long-term continuous ambulatory ECG monitor compared with alternative devices.

Conclusion

The economic literature review found no evidence of a direct comparison between the long-term continuous ECG monitor and the external cardiac loop recorder.

BUDGET IMPACT ANALYSIS

We conducted a budget impact analysis from the perspective of the Ontario Ministry of Health and Long-Term Care to determine the estimated cost burden of continuing to use long-term continuous monitors as compared with external loop recorders. All costs are reported in 2016 Canadian dollars. A 5-year time horizon was selected.[23]

Objectives

The objective of this study was to assess the budget impact, within the context of the Ontario Ministry of Health and Long-Term Care, of continuing to publicly fund long-term continuous ambulatory ECG monitors compared with external cardiac loop recorders for the diagnosis of symptomatic cardiac arrhythmia.

Methods

Target Population

We used administrative billing data from the Ontario Health Insurance Plan (OHIP) for 2006 to 2014, provided by IntelliHealth Ontario, to determine the volume of claims, physician visits, and number of patients related to long-term ambulatory ECG tests. The data included tests that used a long-term continuous monitor (with either 3 to 13 days of recording capacity or with 14 or more days capacity) or an external loop recorder. Table 3 shows the procedure codes used to identify long-term ambulatory ECG test volumes for our analysis.

Table 3: Ontario Physician Schedule of Benefits Codes for Long-Term Ambulatory ECG Testing

Diagnostic Device	Fee Code And Diagnostic Service
LCEM 3–13 days	G684: Technical component – recording G685: Technical component – scanning G659: Professional component
LCEM ≥ 14 days	G647: Technical component – recording G648: Technical component – scanning G649: Professional component
ECLR	G692: Technical component G649: Professional portion

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.
Source: Ontario Ministry of Health and Long-Term Care, Schedule of Benefits, 2016.[24]

Volumes of ECG Tests

We noted minor differences between the number of tests identified through the technical and professional components of the fee codes listed in Table 3. We used test volumes corresponding to the professional components to extrapolate for future years.

Table 4 presents the number of long-term ambulatory ECG tests performed in Ontario between 2006 and 2014 with long-term continuous monitors and external loop recorders. Detailed historical data for the same years on the number of patients, physician visits, and tests performed using the two types of ambulatory ECG monitors are presented in Appendix 5, Tables A2 to A4.

Table 4: Volumes of Long-Term Ambulatory ECG Tests Performed in Ontario, 2006–2014

Year	LCEM Tests, ≥ 14 Days, n	LCEM Tests, 3–13 Days, n	Total LCEM Tests, n	ECLR Tests, n	Overall Tests, N
2006	NA[a]	638	638	20,398	21,036
2007	NA	1,111	1,111	26,886	27,997
2008	NA	1,884	1,884	31,819	33,703
2009	NA	2,575	2,575	40,675	43,250
2010	NA	2,669	2,669	51,637	54,306
2011	712	4,210	4,922	57,973	62,895
2012	6,383	8,323	14,706	47,782	62,488
2013	10,320	16,728	27,048	47,779	74,827
2014	9,297	27,894	37,191	47,437	84,628

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor; NA, not applicable.
[a]Public funding for tests lasting ≥ 14 days began in 2011.
Source: Data provided by Ontario Ministry of Health and Long-Term Care, IntelliHealth Ontario.

We estimated the total number of long-term ambulatory ECG tests for 2016 to 2020 by a linear trend projection using methods of ordinary least squares based on the historical data (2006 to 2014) from IntelliHealth Ontario.

Main Assumptions

This analysis used the following major assumptions:

- There are no adverse events associated with the use of either type of monitor
- No other devices in this class enter the market during the 5 years of the analysis
- The unit price of testing remains constant
- The overall volume of tests increases along a linear trend similar to the trend observed from 2006 to 2014

Base Case

In the base case analysis, we compared the “current state” with an increasing rate of uptake for long-term continuous ECG testing—where use of these monitors grows linearly over the 5-year time horizon (2016–2020) based on the 2011–2014 trend. The current state is defined as the 2014 proportions of all testing that are performed using each type of cardiac monitor projected statically over the future time horizon. Under the current state, 44% of tests each year are performed using long-term continuous monitors (25% of these are 14 days or longer, 75% are 3 to 13 days) and 56% of tests are performed using external loop recorders. Table 5 shows the volumes of tests projected under the current state for each year, and Figure 5 graphically presents the historical trends and projected volumes.

Table 5: Expected Volumes of Long-Term Ambulatory ECG Tests Under the Current State

Year	LCEM Tests, ≥ 14 Days, n[a]	LCEM Tests, 3–13 Days, n[b]	Total LCEM Tests, n[c]	ECLR Tests, n[d]	Overall Tests, N
2016	10,864	32,594	43,458	55,430	98,888
2017	11,728	35,188	46,916	59,841	106,756
2018	12,592	37,781	50,373	64,251	114,624
2019	13,457	40,374	53,831	68,661	122,492
2020	14,321	42,968	57,289	73,071	130,360

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.
[a]25% of total LCEM tests.
[b]75% of total LCEM tests.
[c]44% of overall tests.
[d]56% of overall tests.

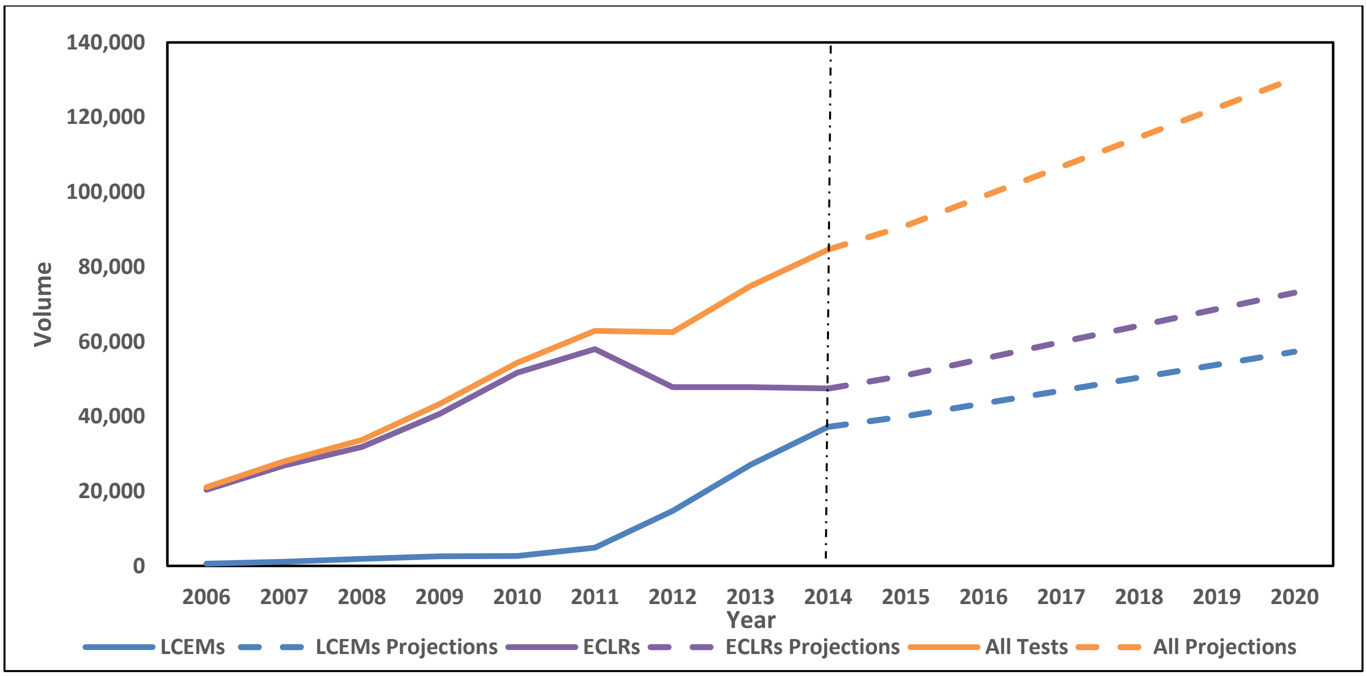

Figure 5: Expected Volumes of Long-Term Ambulatory ECG Tests Under the Current State

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.
Current state: 44% of all tests use a long-term continuous monitor, and 56% of all tests use an external cardiac loop recorder.
Source: 2006–2014 data provided by Ontario Ministry of Health and Long-Term Care, IntelliHealth Ontario.

We assumed that as the uptake of long-term continuous ECG monitors increases, the number of tests done via external loop recorders is then the difference between the overall volume of tests and those done by long-term continuous monitors. We chose 2011 to 2014 as the basis period for this extrapolation because 2011 was the first year that Ontario publicly funded long-term continuous ECG monitoring of 14 or more days' duration. Table 6 and Figure 6 present the expected number of long-term ambulatory ECG tests based on an increasing uptake rate for long-term continuous monitors.

Table 6: Expected Volume of Long-Term Ambulatory ECG Tests Under Increasing Uptake of Long-Term Continuous Monitors

Year	LCEM Tests, ≥ 14 Days, n[a]	LCEM Tests, 3–13 Days, n[b]	Total LCEM Tests, n[c]	ECLR Tests, n[d]	Overall Tests, N
2016	14,792	44,377	59,169	39,720	98,888
2017	17,521	52,563	70,084	36,672	106,756
2018	20,250	60,749	80,999	33,625	114,624
2019	22,978	68,935	91,914	30,578	122,492
2020	25,707	77,121	102,828	27,531	130,360

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.
[a] 25% of total LCEM tests.
[b] 75% of total LCEM tests.
[c] Assumes total LCEMs grow along 2011–2014 linear trend.
[d] Overall tests minus total LCEM tests.

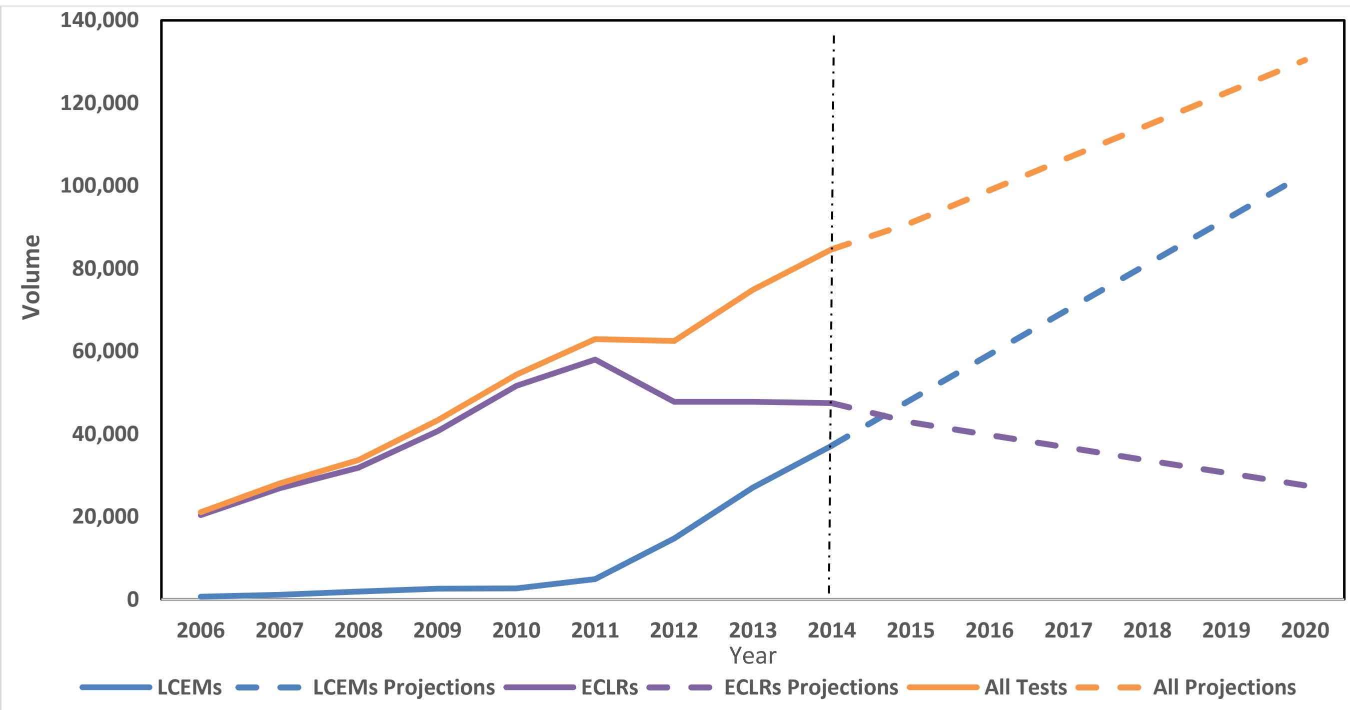

Figure 6: Expected Volumes of Long-Term Ambulatory ECG Tests Under Increasing Uptake of Long-Term Continuous Monitors

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.
Note: Uptake rate of LCEM tests grows along the 2011–2014 linear trend.
Source: 2006–2014 data provided by Ontario Ministry of Health and Long-Term Care, IntelliHealth Ontario.

Scenario Analyses

We examined four scenarios with different rates of uptake for long-term continuous monitors and external loop recorders during the years 2016 to 2020.

Scenario 1

In scenario 1, the volume of external loop recorder tests decreases by 25% annually. The use of long-term continuous monitors correspondingly increases annually by 30%, 20%, 15%, 12%, and 10% (i.e., the difference between total volumes and external loop recorder volumes).

The proportion of tests using the monitor that records for 14 days or longer (25%) and the 3- to 13-day device (75%), as a percentage of all tests done by long-term continuous monitors, was assumed to be constant over the time horizon.

Table 7 presents the projected volumes of long-term ambulatory ECG tests under scenario 1. This scenario is graphically presented in Appendix 5, Figure A1.

Table 7: Scenario 1, Expected Volumes of Long-Term Ambulatory ECG Tests

Year	LCEM Tests, ≥ 14 Days, n[a]	LCEM Tests, 3–13 Days, n[b]	Total LCEM Tests, n[c]	ECLR Tests, n[d]	Overall Tests, N
2016	18,051	54,154	72,205	26,683	98,888
2017	21,686	65,058	86,744	20,012	106,756
2018	24,904	74,711	99,615	15,009	114,624
2019	27,809	83,426	111,235	11,257	122,492
2020	30,479	91,438	121,917	8,443	130,360

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.
Scenario 1: ECLR tests decrease by 25% annually; LCEM tests grow by 30%, 15%, 12%, and 10% annually.
[a]25% of total LCEM tests.
[b]75% of total LCEM tests.
[c]Overall tests minus total ECLR tests.
[d]Decreases by 25% annually.

Scenario 2

In this scenario, the volumes of tests using external loop recorders increase linearly along the 2006–2014 trend. The volume of tests using long-term continuous monitors increases at a rate calculated by the difference between overall volumes and external loop recorder volumes. Table 8 presents the projected volumes of long-term ambulatory ECG tests under scenario 2. A graphic presentation of this scenario analysis is in Appendix 5, Figure A2.

Table 8: Scenario 2, Expected Volumes of Long-Term Ambulatory ECG Tests

Year	LCEM Tests, ≥ 14 Days, n[a]	LCEM Tests, 3–13 Days, n[b]	Total LCEM Tests, n[c]	ECLR Tests, n[d]	Overall Tests, N
2016	8,877	26,630	35,506	63,382	98,888
2017	9,927	29,780	39,707	67,050	106,756
2018	10,977	32,930	43,907	70,717	114,624
2019	12,027	36,080	48,107	74,385	122,492
2020	13,077	39,230	52,307	78,053	130,360

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.
Scenario 2: ECLR tests increase along the 2006–2014 linear trend.
[a]25% of total LCEM tests.
[b]75% of total LCEM tests.
[c]Overall tests minus total ECLR tests.
[d]Increases along 2006–2014 linear trend.

Scenario 3

In this scenario, only testing by long-term continuous monitor is publicly funded and tests done by external loop recorder are not funded. Detailed volumes associated with this scenario are shown in Table 9.

Table 9: Scenario 3, Expected Volumes of Long-Term Ambulatory ECG Tests

Year	LCEM Tests, ≥ 14 Days, n[a]	LCEM Tests, 3–13 Days, n[b]	Total LCEM Tests, n[c]	ECLR Tests, n	Overall Tests, N
2016	24,722	74,166	98,888	0	98,888
2017	26,689	80,067	106,756	0	106,756
2018	28,656	85,968	114,624	0	114,624
2019	30,623	91,869	122,492	0	122,492
2020	32,590	97,770	130,360	0	130,360

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.
Scenario 3: only LCEM tests are publicly funded.
[a]25% of total LCEM tests.
[b]75% of total LCEM tests.
[c]Same as overall tests (total volumes).

Scenario 4

In this scenario, we assumed that only tests by external loop recorder are publicly funded. The volumes of these tests are equal to the overall volumes of tests. Table 10 shows the volumes of tests in scenario 4.

Table 10: Scenario 4, Expected Volumes of Long-Term Ambulatory ECG Tests

Year	LCEM Tests, ≥ 14 Days, n	LCEM Tests, 3–13 Days, n	Total LCEM Tests, n	ECLR Tests, n[a]	Overall Tests, N
2016	0	0	0	98,888	98,888
2017	0	0	0	106,756	106,756
2018	0	0	0	114,624	114,624
2019	0	0	0	122,492	122,492
2020	0	0	0	130,360	130,360

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.
Scenario 4: only ECLR tests are publicly funded.
[a]Same as overall tests (total volumes).

Resources and Costs

Testing Cost

Table 11 shows the cost of long-term ambulatory ECG testing. Costs include the technical and professional components, obtained from the Ontario Schedule of Benefits, Diagnostic and Therapeutic Procedures.[24] We assumed costs were fixed over the time horizon of the analysis.

Table 11: Unit Costs of Long-Term Ambulatory ECG Tests

Diagnostic Device	Unit Cost, $ CAD 2016	Fee Code And Diagnostic Services
LCEM 3–13 days	71.65	G684: Technical component – recording
	98.10	G685: Technical component – screening
	95.85	G659: Professional component
	265.60	**Total**
LCEM ≥ 14 days	112.65	G647: Technical component – recording
	164.00	G648: Technical component – screening costs
	122.25	G649: Professional component
	398.90	**Total**
ECLR	168.45	G692: Technical component
	122.25	G649: Professional portion
	290.70	**Total**

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.
Source: Ontario Ministry of Health and Long-Term Care, 2016.[24]

Analysis

For the base case and scenario analyses, we obtained the total annual cost estimates for both types of long-term ambulatory ECG testing by multiplying annual volumes of tests for each type of device by their respective unit prices.[24]

We obtained the budget impact for the base case by subtracting the sum of the total costs of each type of long-term ambulatory ECG testing under the current state from the total cost of all testing under an increasing uptake rate for long-term continuous monitors. Similarly, in the scenario analyses, we subtracted the total costs of all testing under the current state from the total costs of testing under each of the four scenarios. We calculated the budget impact for each year of our time horizon, 2016 to 2020.

Expert Consultation

In April and May 2016, we consulted experts on the practice of ECG testing using long-term ambulatory devices. Members of the consultation were physicians specialized in cardiology and electrophysiology.

The role of the expert advisors was to contextualize the evidence and support our research through insights into the demographics of the target populations and the nature, patterns, safety, and frequency of testing. We also solicited experts' views on the potential use of other new technology (mobile cardiac outpatient telemetry) for diagnosing symptomatic arrhythmias.

Results

Base Case

Table 12 presents the results (total costs and net budget impact) of our base case analysis. Detailed calculations are presented in Appendix 6, Tables A5 to A7.

We estimated that the total cost of funding long-term ambulatory ECG testing in Ontario in the current state would range from $29.1 million in 2016 to $38.4 million in 2020. The net budget impact of increasing use of long-term continuous monitors and decreasing use of external loop recorders, as compared with the current state, would range from $0.13 million in 2016 to $0.37 million in 2020.

Table 12: Results of Base Case Analysis, Total Costs and Net Budget Impact of an Increasing Uptake Rate for Long-Term Continuous ECG Monitors vs. Constant Current State

			$ million[a]		
Year	**2016**	**2017**	**2018**	**2019**	**2020**
Current state: constant proportions of ECLR tests (56%) and LCEM tests (44%)	29.10	31.42	33.74	36.05	38.37
Increase in LCEM tests along 2011–2014 linear trend	29.23	31.61	33.99	36.36	38.74
Net budget impact	0.13	0.19	0.25	0.31	0.37

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.
[a] All costs are 2016 Canadian dollars.

Scenario Analysis

Table 13 shows the total cost and net budget impact associated with each of the four scenarios.

Under scenario 4, in which only testing by external loop recorders is publicly funded, the total costs of testing are the smallest, ranging from $28.8 million in 2016 to $37.9 million in 2020. The net budget impact in this scenario indicates that modest savings would be realized, from $0.36 million in 2016 to $0.47 million in 2020, compared to the current state. Alternatively, if only tests by long-term continuous monitors were funded (scenario 3), additional costs ranging from $0.46 million in 2016 to $0.60 million in 2020 would be expected.

Table 13: Results of Scenario Analysis, Total Costs and Net Budget Impact

	$, million[a]				
Scenario	**2016**	**2017**	**2018**	**2019**	**2020**
1) ECLR tests decrease by 25% annually, LCEM tests grow by 30%, 20%, 15%, 12%, and 10% annually	29.34	31.75	34.14	36.52	38.90
Net budget impact[b]	0.24	0.33	0.41	0.47	0.53
2) ECLR tests increase along 2006–2014 linear trend	29.04	31.36	33.68	36.00	38.33
Net budget impact[b]	−0.07	−0.06	−0.05	−0.05	−0.04
3) Only LCEM tests are publicly funded	29.56	31.91	34.26	36.62	38.97
Net budget impact[b]	0.46	0.49	0.53	0.56	0.60
4) Only ECLR tests are publicly funded	28.75	31.03	33.32	35.61	37.90
Net budget impact[b]	−0.36	−0.39	−0.41	−0.44	−0.47

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.
[a]All costs are 2016 Canadian dollars.
[b]Scenario total costs are compared with the current state total costs (Table 11).

Discussion

This budget impact analysis revealed that the use of long-term continuous ECG monitors has grown steadily in Ontario since these tests became publicly funded in 2006—and particularly since 2011 when testing of 14 days' duration or longer began to be covered. The use of external cardiac loop recorders has correspondingly declined. If these trends continue, ongoing public funding of long-term continuous ambulatory ECG monitoring could result in an additional cost in Ontario of $0.13 million to $0.37 million per year over the next 5 years. The greatest costs were associated with the scenario where only tests done by a long-term continuous monitor are publicly funded. The greatest cost savings were associated with the scenario where only tests via external loop recorder are publicly funded. However, all of these scenarios relied on a set of assumptions, including no changes to the fee schedule.

In this analysis, we included only the costs of diagnostic testing. Costs of adverse events were excluded because the only reported adverse event, skin reactions, are occasionally associated with the use of either type of device and thus would yield negligible differences in costs.[25,26] Costs of the devices were also excluded since these costs are borne by physicians or hospitals.

This analysis has several strengths. First, we obtained historical data for 2006 to 2014 from the IntelliHealth Ontario data system and thus were able to create a reliable trend-based model to forecast future claims. Second, we received experts' insights into the nature of long-term ambulatory ECG testing for patients with arrhythmia and thus were able to develop the possible scenarios for our analysis. Finally, to our knowledge, this analysis is the first budget impact assessment that has compared the use of long-term continuous ECG monitors and external cardiac loop recorders for diagnosis of symptomatic arrhythmia.

There were also several limitations to this analysis. First, we could not draw on insights from past research because we found no evidence from the cost-effectiveness literature that directly compared long-term continuous ECG monitors and external cardiac loop recorders for our target population. Second, projections into volumes of long-term ambulatory ECG testing were derived based on historical data, which reflect current clinical practice in Ontario. While this is a strength of the analysis (as noted above), it also may have given rise to an under- or overestimation of values. Clinical practice may evolve, affecting the volumes of testing, total costs, and net budget impact of each type of test. Third, we assumed a constant unit price (OHIP fee) for long-term ambulatory ECG testing. A change in price would alter the total costs and the net budget impact. Finally, we assumed that no new technology for long-term ambulatory ECG testing would enter the local market. If a new technology were to become available and be publicly funded, this would likely alter the prices and volumes of all competing technologies.

Conclusion

Overall, our analysis suggests that greater use of long-term continuous ambulatory ECG monitors compared with external cardiac loop recorders will result in additional expenditure over the next 5 years.

ABBREVIATIONS

CI	Confidence interval
ECG	Electrocardiography
GRADE	Grading of Recommendations Assessment, Development, and Evaluation
ICER	Incremental cost-effectiveness ratio
OHIP	Ontario Health Insurance Plan
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-analyses
QALY	Quality-adjusted life-year
RD	Risk difference

GLOSSARY

Budget impact analysis	An analysis of the effect of a program or action on a budget over some specified period of time.
Cost-effective	Good value for money. The overall benefit of the technique or intervention justifies the cost.
Incremental cost-effectiveness ratio (ICER)	Determines "a unit of benefit" for an intervention by dividing the incremental cost by the incremental effectiveness. The incremental cost is the difference between the cost of the treatment under study and an alternative treatment. The incremental effectiveness is usually measured as additional years of life or as "quality-adjusted life years."
Indirect comparison	A method to evaluate the relative benefits of treatments or interventions of interest by comparing them against a common standard. This method may be used when there are no studies directly comparing the technology under examination.
Meta-regression	A tool used in meta-analysis (a study of studies) to examine the impact of certain variables on the effect observed in different studies. A meta-analysis is a study of existing studies, merging and contrasting their results.
Network meta-analysis	An analysis that compares three or more treatments or interventions, based on the results of existing studies. The existing studies may be direct comparisons of interventions within studies or indirect comparisons across studies based on a common comparator.
Quality-adjusted life-year (QALY)	A measurement that takes into account both the number of years gained by a patient from a procedure and the quality of those extra years (ability to function, freedom from pain, etc.). The QALY is commonly used as an outcome measure in cost–utility analyses.
Risk difference	The difference between the observed risks (proportions of individuals with the outcome of interest) in the two groups.
Scenario analysis	An analysis exploring a range of possible outcomes for an action by projecting the effects of different future events.

APPENDICES

Appendix 1: Literature Search Strategies

Clinical Literature Search Strategy

Database: EBM Reviews - Cochrane Central Register of Controlled Trials <December 2015>, EBM Reviews - Cochrane Database of Systematic Reviews <2005 to January 13, 2016>, EBM Reviews - Database of Abstracts of Reviews of Effects <2nd Quarter 2015>, EBM Reviews - Health Technology Assessment <4th Quarter 2015>, EBM Reviews - NHS Economic Evaluation Database <2nd Quarter 2015>, Embase <1980 to 2016 Week 02>, All Ovid MEDLINE(R) <1946 to Present>

Search Strategy:

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1 exp Arrhythmias, Cardiac/ (502879)
2 (arr?ythmia* or (cardiac adj (dysr?ythmia* or disr?ythmia*))).tw. (164796)
3 (((atrial or auricular or ventricular) adj fibrillation*) or a-fib or afib).tw. (161323)
4 (bradycardia* or bradyarr?ythmia*).tw. (45401)
5 brugada*.tw. (6207)
6 (tachycardia* or tachyarr?ythmia* or Torsade* de Pointes or (rhythm* adj2 accelerated)).tw. (135027)
7 (flutter* adj (auricular or atria* or atrium* or ventric*)).tw. (350)
8 ((premature or ectop* or abnormal*) adj2 (heartbeat* or heart-beat* or cardiac or beat$1 or rhythm* or ventric* or atria* or atrium*)).tw. (46031)
9 extrasystole*.tw. (6090)
10 ((block* or dissociation*) adj2 (heart or atrioventric* or atrio-ventric* or auriculoventric* or auriculo-ventric* or bundle branch or fascicular or sinoatrial)).tw. (49091)
11 (adam* adj stokes).tw. (1150)
12 ((sinus node* or sick sinus*) adj (dysfunction* or disease*)).tw. (3498)
13 (long qt syndrome* or Andersen or Jervell-Lange Nielsen or Romano-Ward or preexcitation* or pre-excitation* or lown-ganong-levine or qrs complex* or wolf-parkinson-white or wpw or ventricular excitation*).tw. (30527)
14 parasystole*.tw. (794)
15 exp *Dyspnea/ (17343)
16 ((breath adj2 shortness*) or dyspnea* or breathlessness*).tw. (95934)
17 *Dizziness/ (3336)
18 (light-headed* or lightheaded* or dizz?ness or orthosta*).tw. (63910)
19 *Chest Pain/ (9226)
20 (chest adj pain*).tw. (67048)
21 palpitation*.tw. (14193)
22 *Syncope/ (13897)
23 (syncop* or presyncop* or (drop adj attack*) or faint*).tw. (55198)
24 or/1-23 (927020)
25 Electrocardiography, Ambulatory/ (128094)
26 ((ambulatory or ambulant or dynamic or continuous* or outpatient* or out-patient* or out-of-hospital* or remote or longterm or long-term or extended) adj3 (electrocardiogra* or electro-cardiogra* or electric-cardiogra* or ECG or ECGs or EKG or EKGs or cardiac monitor*)).tw. (17694)
27 (AECG or AECGs).tw. (427)
28 (patch monitor* or patch device* or (loop* adj3 external)).tw. (1267)

29 or/25-28 (142472)
30 24 and 29 (60449)
31 exp Animals/ not (exp Animals/ and Humans/) (12784312)
32 30 not 31 (47380)
33 Case Reports/ or Comment.pt. or Editorial.pt. or Letter.pt. or Congresses.pt. (4492385)
34 32 not 33 (44751)
35 limit 34 to (english language and yr="1983 -Current") [Limit not valid in CDSR,DARE; records were retained] (24244)
36 35 use pmoz,cctr,coch,dare,clhta,cleed (6700)
37 exp heart arrhythmia/ (320839)
38 (arr?ythmia* or (cardiac adj (dysr?ythmia* or disr?ythmia*))).tw. (164796)
39 (((atrial or auricular or ventricular) adj fibrillation*) or a-fib or afib).tw. (161323)
40 (bradycardia* or bradyarr?ythmia*).tw. (45401)
41 brugada*.tw. (6207)
42 (tachycardia* or tachyarr?ythmia* or Torsade* de Pointes or (rhythm* adj2 accelerated)).tw. (135027)
43 (flutter* adj (auricular or atria* or atrium* or ventric*)).tw. (350)
44 ((premature or ectop* or abnormal*) adj2 (heartbeat* or heart-beat* or cardiac or beat$1 or rhythm* or ventric* or atria* or atrium*)).tw. (46031)
45 extrasystole*.tw. (6090)
46 ((block* or dissociation*) adj2 (heart or atrioventric* or atrio-ventric* or auriculoventric* or auriculo-ventric* or bundle branch or fascicular or sinoatrial)).tw. (49091)
47 (adam* adj stokes).tw. (1150)
48 ((sinus node* or sick sinus*) adj (dysfunction* or disease*)).tw. (3498)
49 (long qt syndrome* or Andersen or Jervell-Lange Nielsen or Romano-Ward or preexcitation* or pre-excitation* or lown-ganong-levine or qrs complex* or wolf-parkinson-white or wpw or ventricular excitation*).tw. (30527)
50 parasystole*.tw. (794)
51 exp *dyspnea/ (17343)
52 ((breath adj2 shortness*) or dyspnea* or breathlessness*).tw. (95934)
53 *dizziness/ (3336)
54 (light-headed* or lightheaded* or dizz?ness or orthosta*).tw. (63910)
55 *thorax pain/ (8452)
56 (chest adj pain*).tw. (67048)
57 palpitation*.tw. (14193)
58 exp *faintness/ (1791)
59 (syncop* or presyncop* or (drop adj attack*) or faint*).tw. (55198)
60 or/37-59 (867166)
61 electrocardiography monitoring/ (17294)
62 ambulatory monitoring/ and electrocardiography/ (796)
63 recorder/ (1418)
64 ((ambulatory or ambulant or dynamic or continuous* or outpatient* or out-patient* or out-of-hospital* or remote or longterm or long-term or extended) adj3 (electrocardiogra* or electro-cardiogra* or electric-cardiogra* or ECG or ECGs or EKG or EKGs or cardiac monitor*)).tw. (17694)
65 (AECG or AECGs).tw. (427)
66 (patch monitor* or patch device* or (loop* adj3 external)).tw. (1267)
67 or/61-66 (34750)
68 60 and 67 (18900)
69 (exp animal/ or nonhuman/) not exp human/ (9558400)
70 68 not 69 (18116)

71 Case Report/ or Comment/ or Editorial/ or Letter/ or conference abstract.pt. (8299619)
72 70 not 71 (13907)
73 limit 72 to (english language and yr="1983 -Current") [Limit not valid in CDSR,DARE; records were retained] (10646)
74 73 use emez (4421)
75 36 or 74 (11121)
76 75 use pmoz (5456)
77 75 use emez (4421)
78 75 use cctr (1159)
79 75 use coch (28)
80 75 use dare (28)
81 75 use clhta (4)
82 75 use cleed (25)

Economic Literature Search Strategy

Database: EBM Reviews - Cochrane Central Register of Controlled Trials <December 2015>, EBM Reviews - Cochrane Database of Systematic Reviews <2005 to January 20, 2016>, EBM Reviews - Database of Abstracts of Reviews of Effects <2nd Quarter 2015>, EBM Reviews - Health Technology Assessment <4th Quarter 2015>, EBM Reviews - NHS Economic Evaluation Database <2nd Quarter 2015>, Embase <1980 to 2016 Week 04>, All Ovid MEDLINE(R) <1946 to Present>
Search Strategy:
----
1 exp Arrhythmias, Cardiac/ (504954)
2 (arr?ythmia* or (cardiac adj (dysr?ythmia* or disr?ythmia*))).tw. (165496)
3 (((atrial or auricular or ventricular) adj fibrillation*) or a-fib or afib).tw. (162265)
4 (bradycardia* or bradyarr?ythmia*).tw. (45533)
5 brugada*.tw. (6240)
6 (tachycardia* or tachyarr?ythmia* or Torsade* de Pointes or (rhythm* adj2 accelerated)).tw. (135492)
7 (flutter* adj (auricular or atria* or atrium* or ventric*)).tw. (351)
8 ((premature or ectop* or abnormal*) adj2 (heartbeat* or heart-beat* or cardiac or beat$1 or rhythm* or ventric* or atria* or atrium*)).tw. (46194)
9 extrasystole*.tw. (6107)
10 ((block* or dissociation*) adj2 (heart or atrioventric* or atrio-ventric* or auriculoventric* or auriculo-ventric* or bundle branch or fascicular or sinoatrial)).tw. (49267)
11 (adam* adj stokes).tw. (1150)
12 ((sinus node* or sick sinus*) adj (dysfunction* or disease*)).tw. (3511)
13 (long qt syndrome* or Andersen or Jervell-Lange Nielsen or Romano-Ward or preexcitation* or pre-excitation* or lown-ganong-levine or qrs complex* or wolf-parkinson-white or wpw or ventricular excitation*).tw. (30614)
14 parasystole*.tw. (794)
15 exp *Dyspnea/ (17410)
16 ((breath adj2 shortness*) or dyspnea* or breathlessness*).tw. (96529)
17 *Dizziness/ (3341)
18 (light-headed* or lightheaded* or dizz?ness or orthosta*).tw. (64176)
19 *Chest Pain/ (9235)
20 (chest adj pain*).tw. (67490)
21 palpitation*.tw. (14270)

22 *Syncope/ (13910)
23 (syncop* or presyncop* or (drop adj attack*) or faint*).tw. (55432)
24 or/1-23 (930836)
25 Electrocardiography, Ambulatory/ (128458)
26 ((ambulatory or ambulant or dynamic or continuous* or outpatient* or out-patient* or out-of-hospital* or remote or longterm or long-term or extended) adj3 (electrocardiogra* or electro-cardiogra* or electric-cardiogra* or ECG or ECGs or EKG or EKGs or cardiac monitor*)).tw. (17735)
27 (AECG or AECGs).tw. (445)
28 (patch monitor* or patch device* or (loop* adj3 external)).tw. (1271)
29 or/25-28 (142888)
30 24 and 29 (60663)
31 economics/ (247067)
32 economics, medical/ or economics, pharmaceutical/ or exp economics, hospital/ or economics, nursing/ or economics, dental/ (713448)
33 economics.fs. (369434)
34 (econom* or price or prices or pricing or priced or discount* or expenditure* or budget* or pharmacoeconomic* or pharmaco-economic*).tw. (655231)
35 exp "costs and cost analysis"/ (494392)
36 cost*.ti. (224919)
37 cost effective*.tw. (236577)
38 (cost* adj2 (util* or efficacy* or benefit* or minimi* or analy* or saving* or estimate* or allocation or control or sharing or instrument* or technolog*)).ab. (147944)
39 models, economic/ (128133)
40 markov chains/ or monte carlo method/ (114761)
41 (decision adj1 (tree* or analy* or model*)).tw. (31997)
42 (markov or markow or monte carlo).tw. (94720)
43 quality-adjusted life years/ (25298)
44 (QOLY or QOLYs or HRQOL or HRQOLs or QALY or QALYs or QALE or QALEs).tw. (47139)
45 ((adjusted adj (quality or life)) or (willing* adj2 pay) or sensitivity analys*s).tw. (91844)
46 or/31-45 (2191808)
47 30 and 46 (1275)
48 Case Reports/ or Comment.pt. or Editorial.pt. or Letter.pt. or Congresses.pt. (4501634)
49 47 not 48 (1219)
50 limit 49 to (english language and yr="1983 -Current") [Limit not valid in CDSR,DARE; records were retained] (1045)
51 50 use pmoz,cctr,coch,dare,clhta (211)
52 30 use cleed (26)
53 or/51-52 (237)
54 exp heart arrhythmia/ (322709)
55 (arr?ythmia* or (cardiac adj (dysr?ythmia* or disr?ythmia*))).tw. (165496)
56 (((atrial or auricular or ventricular) adj fibrillation*) or a-fib or afib).tw. (162265)
57 (bradycardia* or bradyarr?ythmia*).tw. (45533)
58 brugada*.tw. (6240)
59 (tachycardia* or tachyarr?ythmia* or Torsade* de Pointes or (rhythm* adj2 accelerated)).tw. (135492)
60 (flutter* adj (auricular or atria* or atrium* or ventric*)).tw. (351)
61 ((premature or ectop* or abnormal*) adj2 (heartbeat* or heart-beat* or cardiac or beat$1 or rhythm* or ventric* or atria* or atrium*)).tw. (46194)
62 extrasystole*.tw. (6107)

63 ((block* or dissociation*) adj2 (heart or atrioventric* or atrio-ventric* or auriculoventric* or auriculo-ventric* or bundle branch or fascicular or sinoatrial)).tw. (49267)
64 (adam* adj stokes).tw. (1150)
65 ((sinus node* or sick sinus*) adj (dysfunction* or disease*)).tw. (3511)
66 (long qt syndrome* or Andersen or Jervell-Lange Nielsen or Romano-Ward or preexcitation* or pre-excitation* or lown-ganong-levine or qrs complex* or wolf-parkinson-white or wpw or ventricular excitation*).tw. (30614)
67 parasystole*.tw. (794)
68 exp *dyspnea/ (17410)
69 ((breath adj2 shortness*) or dyspnea* or breathlessness*).tw. (96529)
70 *dizziness/ (3341)
71 (light-headed* or lightheaded* or dizz?ness or orthosta*).tw. (64176)
72 *thorax pain/ (8499)
73 (chest adj pain*).tw. (67490)
74 palpitation*.tw. (14270)
75 exp *faintness/ (1812)
76 (syncop* or presyncop* or (drop adj attack*) or faint*).tw. (55432)
77 or/54-76 (870944)
78 electrocardiography monitoring/ (17334)
79 ambulatory monitoring/ and electrocardiography/ (798)
80 recorder/ (1426)
81 ((ambulatory or ambulant or dynamic or continuous* or outpatient* or out-patient* or out-of-hospital* or remote or longterm or long-term or extended) adj3 (electrocardiogra* or electro-cardiogra* or electric-cardiogra* or ECG or ECGs or EKG or EKGs or cardiac monitor*)).tw. (17735)
82 (AECG or AECGs).tw. (445)
83 (patch monitor* or patch device* or (loop* adj3 external)).tw. (1271)
84 or/78-83 (34856)
85 77 and 84 (18956)
86 Economics/ (247067)
87 Health Economics/ or exp Pharmacoeconomics/ (210715)
88 Economic Aspect/ or exp Economic Evaluation/ (383114)
89 (econom* or price or prices or pricing or priced or discount* or expenditure* or budget* or pharmacoeconomic* or pharmaco-economic*).tw. (655231)
90 exp "Cost"/ (494392)
91 cost*.ti. (224919)
92 cost effective*.tw. (236577)
93 (cost* adj2 (util* or efficacy* or benefit* or minimi* or analy* or saving* or estimate* or allocation or control or sharing or instrument* or technolog*)).ab. (147944)
94 Monte Carlo Method/ (48387)
95 (decision adj1 (tree* or analy* or model*)).tw. (31997)
96 (markov or markow or monte carlo).tw. (94720)
97 Quality-Adjusted Life Years/ (25298)
98 (QOLY or QOLYs or HRQOL or HRQOLs or QALY or QALYs or QALE or QALEs).tw. (47139)
99 ((adjusted adj (quality or life)) or (willing* adj2 pay) or sensitivity analys*s).tw. (91844)
100 or/86-99 (1799126)
101 85 and 100 (527)
102 Case Report/ or Comment/ or Editorial/ or Letter/ or conference abstract.pt. (8338018)
103 101 not 102 (441)

104 limit 103 to (english language and yr="1983 -Current") [Limit not valid in CDSR,DARE; records were retained] (394)
105 104 use emez (183)
106 53 or 105 (420)
107 remove duplicates from 106 (340)
108 106 use pmoz (135)
109 106 use emez (183)
110 106 use cctr (36)
111 106 use coch (27)
112 106 use dare (12)
113 106 use clhta (1)
114 106 use cleed (26)

Appendix 2: Brief Theoretical Description of Statistical Methods Used for Clinical Evidence Review

A random effects model for frequentist network meta-analysis under the assumption that transitivity holds

When fitting the random effects model, we assumed that the observed treatment effect θ_i for study i is normally distributed around its mean, δ_i, i.e., $\theta_i \sim N(\delta_i, \sigma_i^2)$. The parameter δ_i was assumed to vary randomly according to normal distribution, i.e., $\delta_{i,ab} \sim N(d_{ab}, \tau^2) = N(d_{ac} - d_{bc}, \tau^2)$, where a and b are treatments of interest, c is a common comparator, and d_{kj} is the effect of treatment k versus j, averaged across all studies. Our interest was to make an inference on d_{kj}.

R sample code used to fit the random effects model for frequentist network meta-analysis

```
#Call the library
 library(netmeta)
#Read the file
 mydata<-read.table("myfile")
#Fit a model
 net2 <-netmeta(TE, seTE, treat1, treat2, studlab, data=mydata, sm="RD",
 comb.random=TRUE)
#Run a forest plot
 forest(net2, ref="CommonComparator",xlab="RD", leftcols="studlab", rightcols=NULL)
```

Description of weighted least square meta-regression

To run a weighted least square meta-regression, we used the weight matrix $\mathbf{W}$ with *n* by *p* dimension, where *n* denotes the number of primary studies and *p* denotes the number of regression coefficients. Each diagonal element $W_{ii} = \frac{1}{\sigma_i^2}$ in $\mathbf{W}$ represented the inverse of variance σ_i^2 for each study i. We weighted studies by $\mathbf{W}$ given the mathematical fact that the solution for the best linear unbiased estimator of the vector of regression coefficients $\boldsymbol{\beta} = (\beta_1, \beta_2, ...\beta_p)$ in the regression model $\mathbf{Y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}$ with the design matrix $\mathbf{X}$ and the vector of residuals $\boldsymbol{\varepsilon}$ is given by $\hat{\boldsymbol{\beta}} = (\mathbf{X}^T\mathbf{W}\mathbf{X})^{-1}\mathbf{X}^T\mathbf{W}\mathbf{Y}$.

R sample code used to fit the weighted least square meta-regression

```
#Specifying the model
 mymodel<-lm( y ~x1+x2+x3, weights= 1/(se^2)
#Getting a summary of estimates
 summary(mymodel)
#Getting confidence intervals
 confint(mymodel)
```

Appendix 3: Evidence Quality Assessment

Risk of Bias

Table A1: Risk of Bias Assessment for Studies Comparing the Effectiveness of Long-Term Ambulatory ECG Monitors

Author, Year	Confounding	Selection Bias	Measurement Errors	Reporting Bias
Barrett et al, 2014[7]	N	Y	N	N
Jabaudon et al, 2004[13]	N	N	N	N
Locati et al, 2014[14]	N	N	N	N
Manina et al, 2014[8]	N	N	N	N
Mlynarczyk et al, 2015[15]	N	N	N	N
Pastor-Pérez et al, 2010 (1)[9]	N	N	N	N
Pastor-Pérez et al, 2010 (2)[9]	N	N	N	N
Reiffel et al, 2005 (1)[16]	Y	N	?	N
Reiffel et al, 2005 (2)[16]	Y	N	?	N
Ritter et al, 2013[10]	N	N	N	N
Scherr et al, 2008[11]	N	N	N	N
Stahrenberg et al, 2010[12]	N	N	N	N

Abbreviations: ECG, electrocardiography; N, no; Y, yes; ?, unknown.
Note: Studies compared either a long-term continuous ambulatory ECG monitor or an external cardiac loop recorder with a 24-hour Holter monitor.

Quality of Evidence

As stated by the GRADE Working Group, the final quality score for our network meta-analysis (Table 2) can be interpreted using the following definitions:

High	We are very confident that the true prognosis (probability of future events) lies close to that of the estimate
Moderate	We are moderately confident that the true prognosis (probability of future events) is likely to be close to the estimate, but there is a possibility that it is substantially different
Low	Our confidence in the estimate is limited: the true prognosis (probability of future events) may be substantially different from the estimate
Very Low	We have very little confidence in the estimate: the true prognosis (probability of future events) is likely to be substantially different from the estimate

Appendix 4: Example of a Modified Methodological Checklist for Economic Evaluations

Question topic:		
Study reference:		
Checklist completed by:		
APPLICABILITY (relevance to question under review)		
Item	**Yes/Partly/ No/Unclear/NA**	**Comments**
Is the study population appropriate to the question?		
Are the interventions appropriate to the question?		
Are all relevant interventions compared?		
What country was this study conducted in?		
Is the health care system in which the study was conducted sufficiently similar to Ontario with respect to this question/topic? Explain the ways in which they differ.		
Are estimates of relative treatment effect the same as those included in the clinical report?		
Are costs measured from a health care payer perspective?		
Are non-direct health effects on individuals excluded?		
Are both costs and health effects discounted at an annual rate of 5%?		
Do the estimates of resource use differ from that which would be expected in an Ontario context?		
Is the value of health expressed in terms of quality-adjusted life-years (QALYs)?		
Are changes in health-related quality of life (HRQOL) obtained directly from patients and/or carers?		
Was the valuation of changes in HRQOL (utilities) obtained from a representative sample of the general public?		
Overall judgment (directly applicable/partially applicable/not applicable): If a study is considered not applicable, there is no need to assess its quality.		

Appendix 5: Volumes for Budget Impact Analysis

Number of tests, patients, and testing-related visits by type of testing device for 2006 to 2014 in Ontario are presented in Tables A2 to A4. Figures A1 and A2 show projected volumes for the scenario analyses.

Table A2: Volumes of Patients, Visits, and Tests Performed Using Long-Term Continuous ECG Monitors (≥ 14 Days), OHIP Data, 2011–2014

Year	Code	Description	Patients, N	Visits, N	Tests, N
2011	G647	Technical component – 14 or more days recording	724	739	711
	G648	Technical component – 14 or more days scanning	722	736	708
	G649	Professional component – 14 or more days recording	725	740	712
2012	G647	Technical component – 14 or more days recording	6,168	6,514	6,390
	G648	Technical component – 14 or more days scanning	6,163	6,509	6,384
	G649	Professional component – 14 or more days recording	6,132	6,477	6,383
2013	G647	Technical component – 14 or more days recording	10,030	10,503	10,353
	G648	Technical component – 14 or more days scanning	10,026	10,497	10,346
	G649	Professional component – 14 or more days recording	9,999	10,470	10,320
2014	G647	Technical component – 14 or more days recording	9,113	9,426	9,330
	G648	Technical component – 14 or more days scanning	9,108	9,419	9,315
	G649	Professional component – 14 or more days recording	9,095	9,402	9,297

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor; OHIP, Ontario Health Insurance Plan.
Source: Data provided by Ministry of Health and Long-Term Care, IntelliHealth Ontario.

Table A3: Volumes of Patients, Visits, and Tests Performed Using Long-Term Continuous ECG Monitors (3–13 Days), OHIP Data, 2006–2014

Year	Code	Description	Patients, N	Visits, N	Tests, N
2006	G684	Technical component – 60 hours to 13 days recording	623	641	638
	G685	Technical component – 60 hours to 13 days scanning	578	589	586
	G659	Professional component – 60 hours to 13 days recording	572	583	580
2007	G684	Technical component – 60 hours to 13 days recording	1,089	1,110	1,111
	G685	Technical component – 60 hours to 13 days scanning	1,042	1,060	1,061
	G659	Professional component – 60 hours to 13 days recording	1,054	1,072	1,072
2008	G684	Technical component – 60 hours to 13 days recording	1,826	1,884	1,884
	G685	Technical component – 60 hours to 13 days scanning	1,700	1,755	1,755
	G659	Professional component – 60 hours to 13 days recording	1,701	1,756	1,754
2009	G684	Technical component – 60 hours to 13 days recording	2,339	2,576	2,575
	G685	Technical component – 60 hours to 13 days scanning	2,118	2,358	2,357
	G659	Professional component – 60 hours to 13 days recording	2,167	2,408	2,407
2010	G684	Technical component – 60 hours to 13 days recording	2,593	2,672	2,669
	G685	Technical component – 60 hours to 13 days scanning	2,568	2,647	2,644
	G659	Professional component – 60 hours to 13 days recording	2,575	2,651	2,648
2011	G684	Technical component – 60 hours to 13 days recording	4,168	4,311	4,210
	G685	Technical component – 60 hours to 13 days scanning	4,286	4,445	4,339
	G659	Professional component – 60 hours to 13 days recording	4,244	4,386	4,280
2012	G684	Technical component – 60 hours to 13 days recording	8,216	8,519	8,323
	G685	Technical component – 60 hours to 13 days scanning	8,015	8,300	7,856
	G659	Professional component – 60 hours to 13 days recording	8,062	8,360	7,909
2013	G684	Technical component – 60 hours to 13 days recording	16,437	16,965	16,728
	G685	Technical component – 60 hours to 13 days scanning	15,897	16,391	16,183
	G659	Professional component – 60 hours to 13 days recording	15,651	16,137	15,933

Year	Code	Description	Patients, N	Visits, N	Tests, N
2014	G684	Technical component – 60 hours to 13 days recording	26,770	28,345	27,894
	G685	Technical component – 60 hours to 13 days scanning	25,876	27,361	26,920
	G659	Professional component – 60 hours to 13 days recording	25,702	27,181	26,735

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor; OHIP, Ontario Health Insurance Plan.
Source: Data provided by Ministry of Health and Long-Term Care, IntelliHealth Ontario.

Table A4: Volumes of Patients, Visits, and Tests Performed Using External Cardiac Loop Recorders, OHIP Data, 2006–2014

Year	Code	Description	Patients, N	Visits, N	Tests, N
2006	G692	Technical component	18,571	20,400	20,398
	G690	Professional component, interpretation	18,620	20,387	20,410
2007	G692	Technical component	24,618	26,890	26,886
	G690	Professional component, interpretation	24,804	27,678	27,673
2008	G692	Technical component	28,407	31,870	31,819
	G690	Professional component, interpretation	28,586	32,605	32,568
2009	G692	Technical component	36,926	40,739	40,675
	G690	Professional component, interpretation	37,172	41,087	41,028
2010	G692	Technical component	47,588	51,644	51,637
	G690	Professional component, interpretation	47,997	52,202	52,202
2011	G692	Technical component	55,399	60,092	57,973
	G690	Professional component, interpretation	55,692	60,431	58,302
2012	G692	Technical component	45,084	48,873	47,782
	G690	Professional component, interpretation	45,404	49,535	46,028
2013	G692	Technical component	45,782	48,362	47,779
	G690	Professional component, interpretation	46,321	48,848	48,273
2014	G692	Technical component	47,437	51408	50,815
	G690	Professional component, interpretation	48,133	52139	51,546

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor; OHIP, Ontario Health Insurance Plan.
Source: Data provided by Ministry of Health and Long-Term Care, IntelliHealth Ontario.

Projected Volumes for Scenario Analysis

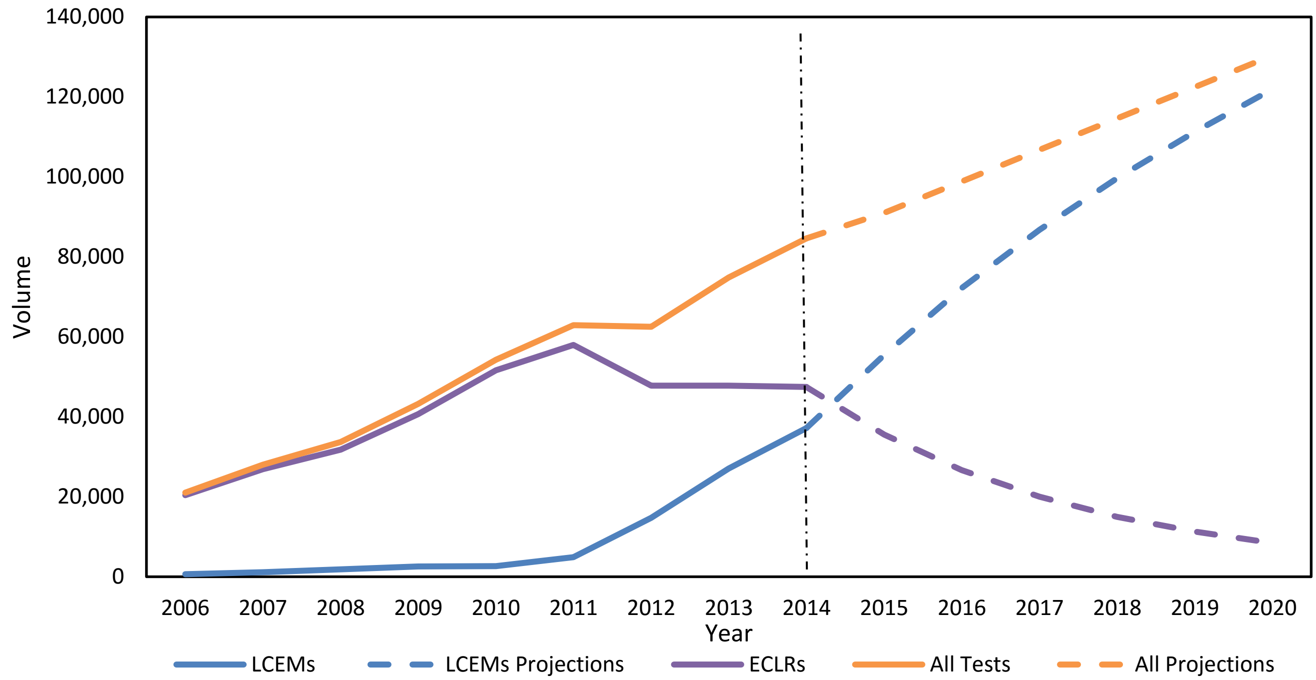

Figure A1: Volumes of Long-Term Ambulatory ECG Testing for Scenario 1

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.
Scenario 1: ECLR tests decrease by 25% annually; LCEM tests grow by 30%, 15%, 12%, and 10% annually.
Source: 2006–2014 data provided by Ministry of Health and Long-Term Care, IntelliHealth Ontario.

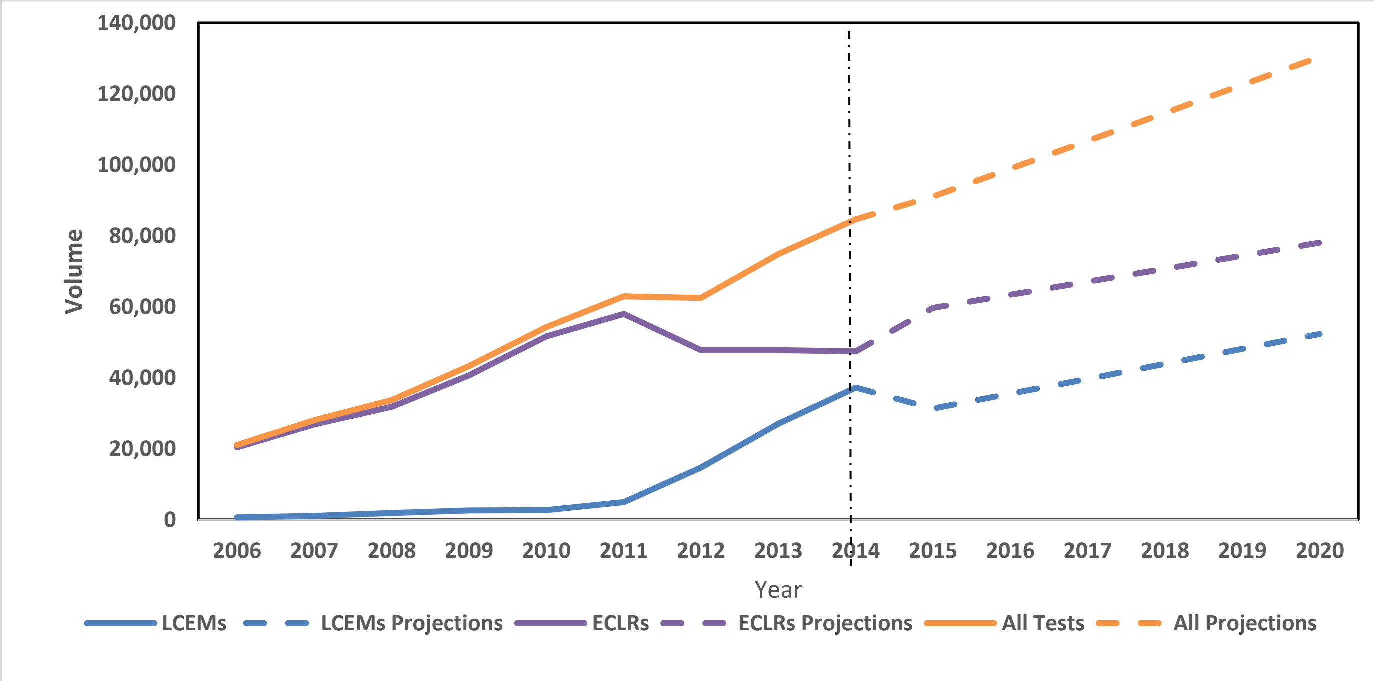

Figure A2: Volumes of Long-Term Ambulatory ECG Testing for Scenario 2

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.
Scenario 2: In 2016–2020, ECLR tests grow along the 2006–2014 linear trend and LCEM test volumes are the difference between overall volumes and ECLR volumes.
Source: 2006–2014 data provided by Ministry of Health and Long-Term Care, IntelliHealth Ontario.

Appendix 6: Detailed Results of Budget Impact Analysis

Results for the Base Case

Table A5: Total Cost for Current State, by Type of Long-Term Ambulatory ECG Device, 2016–2020

Year	$ million, CAD 2016				
	Cost of LCEM Tests, ≥ 14 Days	Cost of LCEM Tests, 3–13 Days	Cost of all LCEM Tests	Cost of ECLR Tests	Overall Cost of all Tests
2016	4.33	8.66	12.99	16.11	29.10
2017	4.68	9.35	14.02	17.40	31.42
2018	5.02	10.03	15.06	18.68	33.74
2019	5.37	10.72	16.09	19.96	36.05
2020	5.71	11.41	17.12	21.24	38.37
Total	25.12	50.17	75.29	93.39	168.68

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.

Table A6: Total Cost of Increased Use of Long-Term Continuous ECG Monitors Based on 2011–2014 Linear Trend, by Type of Testing Device

Year	$ million, CAD 2016				
	Cost of LCEM Tests, ≥ 14 Days	Cost of LCEM Tests, 3–13 Days	Cost of all LCEM Tests	Cost of ECLR Tests	Overall Cost of all Tests
2016	5.90	11.79	17.7	11.55	29.23
2017	6.99	13.96	20.9	10.66	31.61
2018	8.08	16.13	24.2	9.77	33.99
2019	9.17	18.31	27.5	8.89	36.36
2020	10.25	20.48	30.7	8.00	38.74
Total	40.39	80.67	121.06	48.87	169.94

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.

Table A7: Budget Impact for the Base Case, by Type of Testing Device

	$ million, CAD 2016				
	2016	2017	2018	2019	2020
Cost difference for LCEM testing, ≥ 14 days	1.57	2.31	3.05	3.80	4.54
Cost difference for LCEM testing, 3–13 days	3.13	4.61	6.10	7.59	9.07
Cost difference for all LCEM testing	4.70	6.93	9.16	11.38	13.61
Cost difference for ECLR testing	−4.57	−6.74	−8.90	−11.07	−13.24
Net budget impact	0.13	0.19	0.25	0.31	0.37

Abbreviations: ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory electrocardiography monitor.

Results for the Scenario Analyses

Total Costs

Table A8: Total Costs of Testing for Scenario 1 (External Cardiac Loop Recorder Tests Decrease and Long-Term Continuous Monitor Tests Grow), by Type of Device

	$ million, CAD 2016				
Year	Cost of LCEM Tests, ≥ 14 Days	Cost of LCEM Tests, 3–13 Days	Cost of all LCEM Tests	Cost of ECLR Tests	Overall Cost of all Tests
2016	7.20	14.38	21.58	7.77	29.34
2017	8.65	17.28	25.3	5.82	31.75
2018	9.93	19.84	29.78	4.36	34.14
2019	11.09	22.16	33.25	3.27	36.52
2020	12.16	24.29	36.44	2.45	38.90
Total	49.04	97.95	146.99	23.66	170.65

Abbreviations: ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory electrocardiography monitor.
Scenario 1: ECLR tests decrease by 25% annually; LCEM tests grow by 30%, 15%, 12%, and 10% annually.

Table A9: Total Costs of Testing for Scenario 2 (External Loop Recorder Tests Increase Based on 2006–2014 Linear Trend), by Type of Device

	$ million, CAD 2016				
Year	Cost of LCEM Tests, ≥ 14 Days	Cost of LCEM Tests, 3–13 Days	Cost of all LCEM Tests	Cost of ECLR Tests	Overall Cost of all Tests
2016	3.54	7.07	10.61	18.43	29.04
2017	3.96	7.91	11.87	19.49	31.36
2018	4.38	8.75	13.12	20.56	33.69
2019	4.80	9.58	14.38	21.62	36.00
2020	5.22	10.42	15.64	22.69	38.33
Total	21.89	43.73	65.62	102.79	168.41

Abbreviations: ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory electrocardiography monitor.

Table A10: Total Costs of Testing for Scenario 3 (Only Long-Term Continuous Monitors are Publicly Funded for Long-Term Ambulatory ECG Testing), by Type of Device

	$ million, CAD 2016				
Year	Cost of LCEM Tests, ≥ 14 Days	Cost of LCEM Tests, 3–13 Days	Cost of all LCEM Tests	Cost of ECLR Tests	Overall Cost of all Tests
2016	9.86	19.70	29.56	0.00	29.56
2017	10.65	21.27	31.91	0.00	31.91
2018	11.43	22.83	34.27	0.00	34.27
2019	12.22	24.40	36.62	0.00	36.62
2020	13.00	25.97	38.97	0.00	38.97
Total	57.15	114.17	171.33	0.00	171.33

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.

Table A11: Total Costs of Testing for Scenario 4 (Only External Cardiac Loop Recorders Are Publicly Funded for Long-Term Ambulatory ECG Testing), by Type of Device

Year	$ million, CAD 2016				
	Cost of LCEM Tests, ≥ 14 Days	Cost of LCEM Tests, 3–13 Days	Cost of all LCEM Tests	Cost of ECLR Tests	Overall Cost of all Tests
2016	0.00	0.00	0.00	28.75	28.75
2017	0.00	0.00	0.00	31.03	31.03
2018	0.00	0.00	0.00	33.32	33.32
2019	0.00	0.00	0.00	35.61	35.61
2020	0.00	0.00	0.00	37.90	37.90
Total	0.00	0.00	0.00	166.61	166.61

Abbreviations: ECG, electrocardiography; ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory ECG monitor.

Budget Impact

Table A12: Budget Impact for Scenario 1 (External Cardiac Loop Recorder Tests Decrease and Long-Term Continuous Monitor Tests Grow), by Type of Device

	$ million (CAD 2016)				
	2016	2017	2018	2019	2020
Cost difference for LCEM testing, ≥ 14 days	2.87	3.97	4.91	5.73	6.45
Cost difference for LCEM testing, 3–13 days	5.73	7.93	9.81	11.43	12.87
Cost difference for all LCEM testing	8.59	11.91	14.72	17.16	19.32
Cost of ECLR testing	−8.36	−11.58	−14.31	−16.69	−18.79
Net budget impact	0.24	0.33	0.41	0.47	0.53

Abbreviations: ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory electrocardiography monitor.
Scenario 1: ECLR tests decrease by 25% annually; LCEM tests grow by 30%, 15%, 12%, and 10% annually.

Table A13: Budget Impact for Scenario 2 (External Cardiac Loop Recorder Tests Increase Based on 2006–2014 Linear Trend), by Type of Device

	$ million, CAD 2016				
	2016	2017	2018	2019	2020
Cost difference for LCEM testing, ≥ 14 days	−0.79	−0.72	−0.64	−0.57	−0.50
Cost difference for LCEM testing, 3–13 days	−1.58	−1.44	−1.29	−1.14	−0.99
Cost difference for all LCEM testing	−2.38	−2.15	−1.93	−1.71	−1.49
Cost difference for ECLR testing	2.31	2.10	1.88	1.66	1.45
Net budget impact	−0.07	−0.06	−0.05	−0.05	−0.04

Abbreviations: ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory electrocardiography monitor.

Table A14: Budget Impact for Scenario 3 (Only Long-Term Continuous Monitors are Publicly Funded), by Type of Device

	$ million, CAD 2016				
	2016	2017	2018	2019	2020
Cost difference for LCEM testing, ≥ 14 days	5.53	5.97	6.41	6.85	7.29
Cost difference for LCEM testing, 3–13 days	11.04	11.92	12.80	13.68	14.56
Cost difference for all LCEM testing	16.57	17.89	19.21	20.53	21.85
Cost difference for ECLR testing	−16.11	−17.40	−18.68	−19.96	−21.24
Net budget impact	0.46	0.49	0.53	0.57	0.60

Abbreviations: ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory electrocardiography monitor.

Table A15: Budget Impact for Scenario 4 (Only External Loop Recorders are Publicly Funded), by Type of Device

	$ million, CAD 2016				
	2016	2017	2018	2019	2020
Cost difference for LCEM testing, ≥ 14 days	−4.33	−4.68	−5.02	−5.37	−5.71
Cost difference for LCEM testing, 3–13 days	−8.66	−9.35	−10.03	−10.72	−11.41
Cost difference for all LCEM testing	−12.99	−14.02	−15.06	−16.09	−17.12
Cost difference for ECLR testing−	12.63	13.64	14.64	15.65	16.65
Net budget impact	−0.36	−0.39	−0.41	−0.44	−0.47

Abbreviations: ECLR, external cardiac loop recorder; LCEM, long-term continuous ambulatory electrocardiography monitor.

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About Health Quality Ontario

Health Quality Ontario is the provincial advisor on the quality of health care. We are motivated by a single-minded purpose: **Better health for all Ontarians.**

Who We Are.

We are a scientifically rigorous group with diverse areas of expertise. We strive for complete objectivity, and look at things from a vantage point that allows us to see the forest and the trees. We work in partnership with health care providers and organizations across the system, and engage with patients themselves, to help initiate substantial and sustainable change to the province's complex health system.

What We Do.

We define the meaning of quality as it pertains to health care, and provide strategic advice so all the parts of the system can improve. We also analyze virtually all aspects of Ontario's health care. This includes looking at the overall health of Ontarians, how well different areas of the system are working together, and most importantly, patient experience. We then produce comprehensive, objective reports based on data, facts and the voice of patients, caregivers and those who work each day in the health system. As well, we make recommendations on how to improve care using the best evidence. Finally, we support large scale quality improvements by working with our partners to facilitate ways for health care providers to learn from each other and share innovative approaches.

Why It Matters.

We recognize that, as a system, we have much to be proud of, but also that it often falls short of being the best it can be. Plus certain vulnerable segments of the population are not receiving acceptable levels of attention. Our intent at Health Quality Ontario is to continuously improve the quality of health care in this province regardless of who you are or where you live. We are driven by the desire to make the system better, and by the inarguable fact that better has no limit.

About Health Quality Ontario

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