Ontario
Health Quality Ontario
Qualité des services
de santé Ontario

Invasive Monitoring With Pulmonary Artery Catheters in Heart Failure: A Rapid Review

V Costa

December 2012

Invasive Monitoring With Pulmonary Artery Catheters in Heart Failure: A Rapid Review.
December 2012; pp. 1–25.

Suggested Citation

This report should be cited as follows:

Costa V. Invasive monitoring with pulmonary artery catheters in heart failure: a rapid review. Toronto, ON: Health Quality Ontario; 2012 Dec. 25 p. Available from: http://www.hqontario.ca/evidence/publications-and-ohtac-recommendations/rapid-reviews.

Conflict of Interest Statement

All reports prepared by the Division of Evidence Development and Standards at Health Quality Ontario are impartial. There are no competing interests or conflicts of interest to declare.

Rapid Review Methodology

Clinical questions are developed by the Division of Evidence Development and Standards at Health Quality Ontario in consultation with experts, end-users, and/or applicants in the topic area. A systematic literature search is then conducted to identify relevant systematic reviews, health technology assessments, and meta-analyses; if none are located, the search is expanded to include randomized controlled trials (RCTs) and guidelines. Systematic reviews are evaluated using a rating scale developed for this purpose. If the systematic review has evaluated the included primary studies using the GRADE Working Group criteria (http://www.gradeworkinggroup.org/index.htm), the results are reported and the rapid review process is complete. If the systematic review has not evaluated the primary studies using GRADE, the primary studies included in the systematic review are retrieved and a maximum of two outcomes are graded. If no well-conducted systematic reviews are available, RCTs and/or guidelines are evaluated. Because rapid reviews are completed in very short timeframes, other publication types are not included. All rapid reviews are developed and finalized in consultation with experts.

Disclaimer

This rapid review is the work of the Division of Evidence Development and Standards at Health Quality Ontario, and is developed from analysis, interpretation, and comparison of published scientific research. It also incorporates, when available, Ontario data and information provided by experts. As this is a rapid review, it may not reflect all the available scientific research and is not intended as an exhaustive analysis. Health Quality Ontario assumes no responsibility for omissions or incomplete analysis resulting from its rapid reviews. In addition, it is possible that other relevant scientific findings may have been reported since completion of the review. This report is current to the date of the literature search specified in the Research Methods section, as appropriate. This rapid review may be superseded by an updated publication on the same topic. Please check the Health Quality Ontario website for a list of all publications: http://www.hqontario.ca/evidence/publications-and-ohtac-recommendations.

About Health Quality Ontario

Health Quality Ontario is an arms-length agency of the Ontario government. It is a partner and leader in transforming Ontario's health care system so that it can deliver a better experience of care, better outcomes for Ontarians, and better value for money.

Health Quality Ontario strives to promote health care that is supported by the best available scientific evidence. Health Quality Ontario works with clinical experts, scientific collaborators, and field evaluation partners to develop and publish research that evaluates the effectiveness and cost-effectiveness of health technologies and services in Ontario.

Based on the research conducted by Health Quality Ontario and its partners, the Ontario Health Technology Advisory Committee (OHTAC)—a standing advisory subcommittee of the Health Quality Ontario Board—makes recommendations about the uptake, diffusion, distribution, or removal of health interventions to Ontario's Ministry of Health and Long-Term Care, clinicians, health system leaders, and policy makers.

Rapid reviews, evidence-based analyses and their corresponding OHTAC recommendations, and other associated reports are published on the Health Quality Ontario website. Visit http://www.hqontario.ca for more information.

About Health Quality Ontario Publications

To conduct its rapid reviews, Health Quality Ontario and/or its research partners reviews the available scientific literature, making every effort to consider all relevant national and international research; collaborates with partners across relevant government branches; consults with clinical and other external experts and developers of new health technologies; and solicits any necessary supplemental information.

In addition, Health Quality Ontario collects and analyzes information about how a health intervention fits within current practice and existing treatment alternatives. Details about the diffusion of the intervention into current health care practices in Ontario can add an important dimension to the review. Information concerning the health benefits, economic and human resources, and ethical, regulatory, social, and legal issues relating to the intervention may be included to assist in making timely and relevant decisions to optimize patient outcomes.

Permission Requests

How to Obtain Rapid Reviews From Health Quality Ontario

All rapid reviews are freely available in PDF format at the following URL:
http://www.hqontario.ca/evidence/publications-and-ohtac-recommendations/rapid-reviews.

Table of Contents

List of Abbreviations

CI	Confidence interval
HF	Heart failure
HR	Hazard ratio
IQR	Interquartile range
ITT	Intention-to-treat
LVEF	Left ventricular ejection fraction
NYHA	New York Heart Association
OR	Odds ratio
PAC	Pulmonary artery catheter
RCT	Randomized controlled trial
SD	Standard deviation

Background

As legislated in Ontario's *Excellent Care for All Act*, Health Quality Ontario's mandate includes the provision of objective, evidence-informed advice about health care funding mechanisms, incentives, and opportunities to improve quality and efficiency in the health care system. As part of its Quality-Based Funding (QBF) initiative, Health Quality Ontario works with multidisciplinary expert panels (composed of leading clinicians, scientists, and administrators) to develop evidence-based practice recommendations and define episodes of care for selected disease areas or procedures. Health Quality Ontario's recommendations are intended to inform the Ministry of Health and Long-Term Care's Health System Funding Strategy.

For more information on Health Quality Ontario's Quality-Based Funding initiative, visit www.hqontario.ca.

Objective of Analysis

The objective of this analysis was to evaluate the effectiveness of pulmonary artery catheters (PACs) in patients hospitalized with acute heart failure (HF).

Clinical Need and Target Population

Heart failure is a complex condition characterized by impairment of heart function, which may lead to low cardiac output, or to pulmonary or systemic congestion. (1) The condition is more common in older patients, (1) and its incidence has been increasing with the aging of the population, leading to a rise in the number of hospitalizations for the condition. (2) Acute HF presents with a poor prognosis; the risk of death or rehospitalization is estimated to be 30% to 60% within 60 days of hospital admission. (2)

Technology/Technique

PACs can be used to diagnose, monitor, and treat conditions, including congestive heart failure. (3) They provide a measurement of the filling pressure on the right side of the heart and indirect measurement of pulmonary capillary wedge pressure and cardiac output. (4)

Regulatory Status

PACs are licensed by Health Canada as class IV devices; (5) licensed indications are listed in Table 1 (personal communication, Health Canada, October 9, 2012).

Table 1: Health Canada Licensed Indications for PACs

Licence #	Indication
14764	Flow-directed PACs that allow the continuous, combined hemodynamic monitoring of cardiac output, intracardiac pressures, oxygen saturation, and intracardiac pacing
70730	PACs designed for use as a diagnostic tool. Catheter models are available to allow the physician to measure intracardiac pressures, sample mixed venous blood, and infuse solutions in adult or pediatric patients. These catheters are designed for use at the bedside and in the cardiac catheterization laboratory, surgical suite, post-anaesthesia recovery unit, and other specialized critical care units
14186	PACs that allow for hemodynamic pressure management, fluid and drug delivery, and blood sampling. They also permit cardiac output via bolus thermodilution injection
13581	PACs for venting of the heart during cardiopulmonary bypass to decompress the heart and prevent ventricular distension

Abbreviation: PAC, pulmonary artery catheter.

Rapid Review

Research Question

What is the effectiveness of PACs in patients hospitalized with acute HF?

Research Methods

Literature Search

A literature search was performed on October 8, 2012, using OVID MEDLINE, OVID MEDLINE In-Process and Other Non-Indexed Citations, OVID EMBASE, the Wiley Cochrane Library, and the Centre for Reviews and Dissemination database for studies published from January 1, 2000, until October 8, 2012. Abstracts were reviewed by a single reviewer and, for those studies meeting the eligibility criteria, full-text articles were obtained. Reference lists were also examined for any additional relevant studies not identified through the search.

Inclusion Criteria

- English language full-reports
- systematic reviews, meta-analyses, health technology assessment reports, randomized controlled trials (RCTs), and guidelines
- studies with at least 20 patients per treatment group in individual studies
- evaluating the use of PACs in patients hospitalized with HF; studies in a patient population not specific to HF but that included HF patients and whose results were presented separately were included

Exclusion Criteria

- studies evaluating PACs in patients presenting with HF and any of the following conditions: acute myocardial infarction, heart transplant, pre–heart transplant, cardio-renal syndrome, dialysis, patients using left ventricular assist devices, acute valvular insufficiency, and patients with other active chronic medical conditions that require acute stabilization, such as chronic obstructive pulmonary disease, stroke, or active bleeding
- studies evaluating PACs in patients with conditions other than HF

Outcomes of Interest

- mortality
- PAC-related complications

Expert Panel

In August 2012, an Expert Advisory Panel on Episode of Care for Congestive Heart Failure was struck. Members of the panel included physicians, personnel from the Ministry of Health and Long-Term Care, and representation from the community laboratories.

The role of the Expert Advisory Panel on Episode of Care for Congestive Heart Failure was to contextualize the evidence produced by Health Quality Ontario and provide advice on the components of a high-quality episode of care for HF patients presenting to an acute care hospital. However, the statements, conclusions, and views expressed in this report do not necessarily represent the views of Expert Advisory Panel members.

Data Presentation and Statistical Analysis

The results of the eligible RCTs are presented as shown in the original publications. Dichotomous variables are presented as absolute numbers and percentages, continuous variables as mean or median, and the measure of spread as provided in the publication.

Quality of Evidence

The quality of individual RCTs was assessed for allocation concealment, blinding of participants and physicians and outcome assessment, attrition (withdrawals and losses to follow-up), and use of the intention-to-treat (ITT) principle in the analysis. (6)

The quality of the body of evidence for each outcome was examined according to the GRADE Working Group criteria. (7) The overall quality was determined to be very low, low, moderate, or high using a step-wise, structural methodology.

Study design was the first consideration; the starting assumption was that RCTs are high quality, whereas observational studies are low quality. Five additional factors—risk of bias, inconsistency, indirectness, imprecision, and publication bias—were then taken into account. Limitations or serious limitations in these areas resulted in downgrading the quality of evidence. Finally, 3 factors that may raise the quality of evidence were considered: large magnitude of effect, dose response gradient, and accounting for all residual confounding factors. (7) For more detailed information, please refer to the latest series of GRADE articles. (7)

As stated by the GRADE Working Group, the final quality score can be interpreted using the following definitions:

High	Very confident that the true effect lies close to that of the estimate of the effect
Moderate	Moderately confident in the effect estimate—the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low	Confidence in the effect estimate is limited—the true effect may be substantially different from the estimate of the effect
Very Low	Very little confidence in the effect estimate—the true effect is likely to be substantially different from the estimate of effect

Results of Literature Search

The database search yielded 245 citations published between January 1, 2000, and October 8, 2012 (with duplicates removed). Articles were excluded based on information in the title and abstract. The full texts of potentially relevant articles were obtained for further assessment.

One study (RCT) met the inclusion criteria. One other meta-analysis evaluated studies in critically ill patients, including HF patients, (8) but its results were presented in critically ill patients as a whole, without specific results in HF patients, (8) and for this reason it could not be included in this report. However, its reference list was hand-searched to identify any additional potentially relevant studies, and 1 additional citation (1 RCT) was included, for a total of 2 included citations.

For each included study, the study design was identified and is summarized below in Table 2, which is a modified version of a hierarchy of study design by Goodman. (9)

Table 2: Body of Evidence Examined According to Study Design

Study Design	Number of Eligible Studies
RCT Studies	
Systematic review of RCTs	
Large RCT	1
Small RCT	1[a]
Observational Studies	
Systematic review of non-RCTs with contemporaneous controls	
Non-RCT with non-contemporaneous controls	
Systematic review of non-RCTs with historical controls	
Non-RCT with historical controls	
Database, registry, or cross-sectional study	
Case series	
Retrospective review, modelling	
Studies presented at an international conference	
Expert opinion	
Total	**2**

Abbreviation: RCT, randomized controlled trial.
[a]1 RCT (10) was considered a small RCT, because only the subpopulation of patients with decompensated heart failure was used in this report.

One RCT, the ESCAPE trial, included patients hospitalized with decompensated HF. (11) The other RCT (PAC-Man), identified through the meta-analysis, consisted of an evaluation in patients hospitalized in intensive care units, but results were presented separately for patients with decompensated HF. (10)

Study Design and Characteristics

The ESCAPE trial (11) was designed to examine whether the increased precision of hemodynamic assessment with PACs would result in improved outcomes compared to clinical assessment alone in patients admitted to hospital with decompensated HF with New York Heart Association (NYHA) class IV symptoms. The ESCAPE trial (11) was stopped prematurely after 433 out of 500 patients were included, as recommended by the data and the safety monitoring board, because of concerns about early adverse events and the low likelihood that a significant difference in the primary endpoint would be reached with PACs.

The PAC-Man trial (10) included patients admitted to intensive care and identified by the treating physician as someone who should be managed using a PAC, 111 of whom had decompensated HF. The sample size was revised during the study when it was observed that patients with higher severity were being included. (10) The study compared the impact of PACs vs. clinical management on hospital mortality. (10) The PAC-Man trial (10) did not specifically mention that patients who required PACs were excluded from the trial; however, 110 out of 1,263 eligible patients were excluded due to lack of equipoise as judged by the treating physician.

The risk of bias assessment was low, therefore the quality of each RCT was deemed moderate (Appendix 2). Details of the design and characteristics of the included studies are presented in Table 3.

Table 3: Study Design and Characteristics

Author, Year, N, Follow-up	Study Population	Interventions, Co-interventions	Study Design	Analysis	Outcomes
Binanay et al., 2005 (ESCAPE) (11) N = 433 (PAC 215, clinical assessment 218) Follow-up: 6 months	Patients hospitalized with decompensated HF, NYHA class IV symptoms (≥ 1 HF admission in previous 12 months, LVEF < 30%) Patients in acute decompensation likely requiring PAC in the 24 hours following randomization were excluded	*Interventions* • PAC + clinical assessment • Clinical assessment only *Co-interventions in both groups* • Medications recommended in guidelines for advanced HF[a] • Any standard therapy for HF	• RCT • Unblinded • Crossover allowed[b]	• ITT • Cox proportional hazards[c]	*Primary* • Number of days alive and out of hospital during follow-up *Secondary* • Time to hospitalization or death • Time to death • Mortality • Physiologic parameters[d] • 6-minute walk test • Quality of life • Resource use and cost
Harvey et al., 2005 (PAC-Man) (10) Acute decompensated HF subpopulation: N = 111 (PAC 55, control 56) Entire study: N = 1,014 (PAC 506, control 508) Follow-up: duration of hospital stay	Patients admitted to adult intensive care; patients who should be managed with PAC	*Interventions* • PAC + clinical management • Clinical management only *Co-interventions in both groups* Alternative less invasive monitoring devices allowed[e]	• RCT stratified by the use of monitoring devices and concomitant conditions • Unblinded • Crossover allowed	• ITT • Cox proportional hazards	***Decompensated heart failure subgroup*** *Primary* • Hospital mortality

Abbreviations: HF, heart failure; ITT, intention to treat; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; PAC, pulmonary artery catheter; RCT, randomized controlled trial.

[a]Investigators were encouraged to primarily use diuretics and vasodilators and to avoid the use of inotropics for routine management. Nesiritide became available during the trial, so no specific recommendation on the use of this drug was provided during the study. The authors set the goal of reducing left ventricular filling pressures to reach a pulmonary capillary wedge pressure of ≤ 15 mm Hg and a right atrial pressure of ≤ 8 mm Hg. They were also encouraged to reduce systemic vascular resistance to normal levels without resulting in symptomatic hypotension. In the clinical assessment arm, medication doses were adjusted until resolution of both the symptoms and signs of congestion. (11) In both PAC and clinical assessment groups, medications were adjusted to reach the following goals: absence of physical signs indicating elevated intracardiac filling pressures, evidence of adequate peripheral perfusion, and serum creatinine ≤ 3.0 mg/dL. (3) Additionally, therapy may also have been adjusted in case of evidence of postural hypotension. (3)

[b]Progressive hemodynamic decompensation leading to the need for high-dose inotropic or mechanical support; inability to wean from intravenous inotropic agents; progressive, oliguric renal insufficiency; refractory symptomatic hypotension; worsening pulmonary edema; and diagnostic uncertainty about the primary process causing the decompensation.

[c]Two analyses performed, 1 censoring patients who undergo cardiac transplantation as having reached the endpoint of death on the day of transplantation, and a second analysis not censoring these patients.

[d]Changes in mitral regurgitation, natriuretic peptide levels, and peak oxygen consumption.

[e]Each study centre could decide a priori to use alternative less invasive cardiac output monitoring devices in both treatment groups.

Study Results

In the ESCAPE trial, (11) PACs were used for a median of 1.9 days; the reason for their use was adjustment of therapy in approximately 92% of patients. In the PAC-Man trial, (10) the first PAC was used for a median of 2 (interquartile range [IQR] 1–3) days, and the total number of days of PAC use was 3 (IQR 2–4). In more than 80% of patients included in the PAC-Man trial, (10) PACs were used to guide vasoactive drug treatment. Less invasive cardiac output monitoring devices were used in 79% of patients in each study group (n = 401 in each group). In the PAC-Man trial, (10) information specific to decompensated HF patients was not available.

No differences in main outcomes were observed between the study groups in the 2 RCTs identified (Tables 4 and 5).

In the ESCAPE trial, (11) the most common complication was PAC-related infections, the number of which was statistically significantly higher in the PAC group. The statistical significance of other complications was not provided. (11) Complications were reported in the PAC-Man (10) patient population as a whole; no rates specific to HF patients were provided.

Due to differences in outcomes studied and follow-up time between the 2 RCTs, their results were not pooled. Moreover, the mortality rates in both the PAC and control arms were remarkably different between the 2 RCTs, raising concerns that the patient populations in both trials were different, and corroborating the decision not to pool the study results.

Table 4: ESCAPE Study Results

Baseline Characteristics	Treatment Withdrawal, Losses to Follow-up, n (%)	Mean Number of Days Alive and Out of Hospital at 6 Months	Mortality in Hospital + 30 days, n (%)	Mortality at 6 Months, n (%)	PAC-Related Complications, n (%)
Mean age, years (SD): PAC 56 (14), control 56 (14) Male, n (%): PAC 159 (74), control 161 (74) Ischemic etiology, n (%): PAC 110 (51), control 105 (49) Mean EF (SD): PAC 0.19 (0.07), control 0.20 (0.06)	Withdrawals: PAC 4 (1.9), control 2 (0.9) Losses to follow-up: PAC 5 (2.3), control 9 (4.1) Cross-over: 21/218 (9.6) to PAC Allocated treatment not received: PAC 17/215 (7.9)	PAC: 133 Control: 135 HR: 1.00 (95% CI 0.82, 1.21) *P* = 0.99	PAC: 10 (4.7) Control: 11 (5.0) OR: 0.97 (95% CI 0.38, 2.22) *P* = 0.97	PAC: 43 (20) Control: 38 (17.4) OR: 1.26 (95% CI 0.78, 2.03) *P* = 0.35	Number of patients with PAC-related complications: 10 (4.6)[a] PAC-related deaths: 0 PAC-related infections: 4 (1.9) vs. 0, *P* = 0.03 Bleeding: 2 (0.9%) Catheter knotting: 2 (0.9) Pulmonary infarction/hemorrhage: 2 (0.9) Ventricular tachycardia: 1 (0.5)

Abbreviations: CI, confidence interval; EF, ejection fraction; HR, hazard ratio; OR, odds ratio; PAC, pulmonary artery catheter; SD, standard deviation.
[a]Includes 1 patient assigned to the clinical assessment group who later received a PAC.

Table 5: PAC-Man Study Results

Baseline Characteristics (Entire Study Population)	Treatment Withdrawal, Losses to Follow-up, n (%) (Entire Study Population)	Hospital Mortality (Decompensated HF), n (%)	PAC-Related Complications, n (%) (Entire Study Population)
Mean age, years (SD): PAC 64.7 (14.3), control 65.3 (13.1) Male, n (%): PAC 287 (57), control 304 (60) Decompensated HF, n (%): PAC 55 (11), control 56 (11)	Withdrawals: PAC 13/486 (2.7), control 14/498 (2.8) (due to patient or relative decision) Cross-over: 24/522 (4.6) to PAC group due to loss of equipoise in 23/24 cases, staff error in 1 case Allocated treatment not received: PAC 34 (6.6) — unsuccessful insertion (n = 14), change in clinical condition (n = 14), safety concerns (n = 6)	PAC: 39 (71) Control: 35 (63) HR: 1.07 (95% CI 0.68, 1.69)	Number of patients with PAC-related complications: 46/486 (9.5) Hematoma at site of insertion: 17 (4) Arrhythmias requiring treatment within 1 hour of insertion: 16 (3); 1 cardiac arrest Pneumothorax: 2 (0.4) Hemothorax: 1 (0.2) Retrieval of lost insertion guidewires from the femoral vein and inferior vena cava: 2 (0.4)

Abbreviations: CI, confidence interval; HF, heart failure; HR, hazard ratio; PAC, pulmonary artery catheter; RCT, randomized controlled trial; SD, standard deviation.

According to the authors of the ESCAPE trial, (11) considering that the PACs are a diagnostic tool, the fact that there was no defined strategy to respond to the hemodynamic information derived from the PACs was a limitation of the study.

The GRADE quality of evidence was considered moderate (Appendix 2).

Conclusions

The RCTs identified in patients hospitalized with HF did not show a statistically significant mortality benefit with the use of PACs compared to clinical assessment. A higher rate of infections associated with the PAC compared to clinical assessment was reported in 1 RCT. Other complications associated with PACs were reported, but their rates were not compared to a control group. The RCT excluded patients who were likely to require PACs within 24 hours following randomization, possibly affecting the generalizability of the results. This is based on moderate quality evidence.

Existing Guidelines for Technology

The recommendations regarding the use of PACs in patients with HF from Canadian, American, and European HF guidelines are summarized below.

Recommendations on the Use of PACs in Patients with HF from HF Guidelines

Guideline	Statements
Canadian Cardiovascular Society (1)	An arterial line with or without pulmonary artery catheterization is recommended if there is evidence of very low cardiac output and poor tissue perfusion *(level of evidence B, class I recommendation)*[a]
American College of Cardiology Foundation/American Heart Association (12)	Invasive monitoring should be performed to guide therapy in patients who are in respiratory distress or with clinical evidence of impaired perfusion in whom the adequacy or excess of intracardiac filling pressures cannot be determined from clinical assessment *(level of evidence C, class I recommendation)*[b] Invasive hemodynamic monitoring can be useful for carefully selected patients with acute HF who have persistent symptoms despite empiric adjustment of standard therapies and: • whose fluid status, perfusion, or systemic or pulmonary vascular resistances are uncertain • whose systolic blood pressure remains low, or is associated with symptoms, despite initial therapy • whose renal function is worsening with therapy • who require parenteral vasoactive agents • who may need consideration for advanced device therapy or transplantation *(level of evidence C, class IIa recommendation)*[b]
European Society of Cardiology (13)	The insertion of PACs for the diagnosis of acute HF is usually unnecessary PACs can be useful to distinguish between a cardiogenic and non-cardiogenic mechanism in complex patients with concurrent cardiac and pulmonary disease, especially when echo/Doppler measurements are difficult to obtain PACs may be useful in hemodynamically unstable patients who are not responding as expected to traditional treatments *(level of evidence: C, class IIa recommendation)*[c]

Abbreviations: HF, heart failure; PAC, pulmonary artery catheter.
[a]Class I: evidence or general agreement that a given procedure or treatment is beneficial, useful and effective. Level B: data derived from a single randomized trial or nonrandomized studies.
[b]Level C: very limited populations evaluated; only consensus opinion of experts, case studies or standard of care. Class IIa: recommendation in favour of treatment or procedure being useful/effective; only diverging expert opinion, case studies, or standard of care. Class I: recommendation that procedure or treatment is useful/effective; only expert opinion, case studies, or standard of care.
[c]Level C: consensus of opinion of the experts and/or small studies, retrospective studies, registries. Class IIa: weight of evidence is in favour of usefulness/efficacy.

Acknowledgements

Editorial Staff
Jeanne McKane, CPE, ELS(D)

Medical Information Services
Kaitryn Campbell, BA(H), BEd, MLIS
Corinne Holubowich, Bed, MLIS
Kellee Kaulback, BA(H), MISt

Episode of Care for Congestive Heart Failure Expert Panel

Name	Title	Organization
Dr. David Alter	Senior Scientist	Institute for Clinical Evaluative Sciences Research Program Director and Associate Staff, The Cardiac and Secondary Prevention Program at the Toronto Rehabilitation Institute-UHN Associate Professor of Medicine, University of Toronto
Dr. Douglas Lee	Scientist	Institute for Clinical Evaluative Sciences
Dr. Catherine Demers	Associate Professor	Division of Cardiology, Department of Medicine McMaster University
Dr. Susanna Mak	Cardiologist	University of Toronto, Department of Medicine, Division of Cardiology, Mount Sinai Hospital
Dr. Lisa Mielniczuk	Medical Director, Pulmonary Hypertension Clinic	University of Ottawa Heart Institute
Dr. Peter Liu	President, International Society of Cardiomyopathy and Heart Failure of the World Heart Federation Director, National C-CHANGE Program Scientific Director/VP Research, University of Ottawa Heart Institute Professor of Medicine	University of Ottawa Heart Institute
Dr. Robert McKelvie	Professor of Medicine, Cardiologist	McMaster University, Hamilton Health Sciences
Dr. Malcolm Arnold	Professor of Medicine	University of Western Ontario, London Health Sciences Centre
Dr. Stuart Smith	Chief of Cardiovascular Services Director, Heart Failure Program	St. Mary's General Hospital
Dr. Atilio Costa Vitali	Assistant Professor of Medicine Division of Clinical Science	Sudbury Regional Hospital

Dr. Jennifer Everson	Physician Lead	Hamilton Niagara Haldimand Brant Local Health Integration Network
Dr. Lee Donohue	Family Physician	Ottawa
Linda Belford	Nurse Practitioner, Practice Leader PMCC	University Health Network
Jane MacIver	Nurse Practitioner Heart Failure/Heart Transplant	University Health Network
Sharon Yamashita	Clinical Coordinator, Critical Care	Sunnybrook Health Sciences Centre
Claudia Bucci	Clinical Coordinator, Cardiovascular Diseases	Sunnybrook Health Sciences Centre
Andrea Rawn	Evidence Based Care Program Coordinator	Grey Bruce Health Network
Darlene Wilson	Registered Nurse	Heart Function Clinic, Trillium Health Centre
Kari Kostiw	Clinical Coordinator	Health Sciences North Ramsey Lake Health Centre
Janet Parr	CHF Patient	
Heather Sherrard	Vice President, Clinical Services	University of Ottawa Heart Institute
Sue Wojdylo	Manager, Case Costing	Lakeridge Health
Jane Chen	Manager of Case Costing	University Health Network
Nancy Hunter	LHIN Liaison & Business Development	Cardiac Care Network of Ontario
Ministry Representatives		
Gary Coleridge	Senior Program Consultant	Ministry of Health and Long-Term Care
Louie Luo	Senior Methodologist	Ministry of Health and Long-Term Care

Appendices

Appendix 1: Literature Search Strategies

Search date: October 08, 2012
Databases searched: OVID MEDLINE, MEDLINE In-Process and Other Non-Indexed Citations, EMBASE; Cochrane Library; CRD

Limits: 2000-current; English
Filters: RCTs, guidelines, health technology assessments, systematic reviews, and meta-analyses

Database: Ovid MEDLINE(R) <1946 to September Week 4 2012>, Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations <October 05, 2012>, Embase <1980 to 2012 Week 40>
Search Strategy:

#	Searches	Results
1	exp Heart Failure/	326098
2	(((cardia? or heart) adj (decompensation or failure or incompetence or insufficiency)) or cardiac stand still or ((coronary or myocardial) adj (failure or insufficiency))).ti,ab.	257301
3	or/1-2	415834
4	Catheterization, Swan-Ganz/ use mesz	2045
5	Swan Ganz Catheter/ use emez	2010
6	(Artery Catheterization/ or Artery Catheter/) and Pulmonary Artery/	1022
7	Pulmonary Artery Catheter/ use emez	1097
8	(pulmonary artery adj (catheter? or catheteriz* or catheteris*)).ti,ab.	6457
9	(Swan-Ganz adj (catheter? or catheteriz* or catheteris*)).ti,ab.	3649
10	or/4-9	12296
11	*Monitoring, Physiologic/ use mesz	16710
12	*Monitoring/ use emez	16413
13	*Hemodynamic Monitoring/ use emez	2415
14	(invasive adj2 monitoring).ti.	1060
15	or/11-14	36238
16	3 and (10 or 15)	2549
17	limit 16 to (controlled clinical trial or randomized controlled trial)	203
18	exp Random Allocation/ use mesz	76053
19	exp Double-Blind Method/ use mesz	117569
20	exp Control Groups/ use mesz	1375
21	exp Placebos/ use mesz	31433
22	Randomized Controlled Trial/ use emez	330404
23	exp Randomization/ use emez	59626
24	exp Random Sample/ use emez	4218
25	Double Blind Procedure/ use emez	111270
26	exp Triple Blind Procedure/ use emez	35
27	exp Control Group/ use emez	38159
28	exp Placebo/ use emez	206020
29	(random* or RCT).ti,ab.	1382124

30	(placebo* or sham*).ti,ab.	448065
31	(control* adj2 clinical trial*).ti,ab.	38323
32	or/18-31	1916411
33	3 and (10 or 15) and 32	330
34	or/17,33	378
35	limit 34 to english language	326
36	limit 35 to yr="2000 -Current"	240
37	exp Practice Guideline/ use emez	278454
38	exp Professional Standard/ use emez	268791
39	exp Standard of Care/ use mesz	581
40	exp Guideline/ use mesz	23104
41	exp Guidelines as Topic/ use mesz	102275
42	(guideline* or guidance or consensus statement* or standard or standards).ti.	219138
43	or/37-42	779183
44	Meta Analysis.pt.	36882
45	Meta Analysis/ use emez	66280
46	Systematic Review/ use emez	53571
47	exp Technology Assessment, Biomedical/ use mesz	8864
48	Biomedical Technology Assessment/ use emez	11395
49	(meta analy* or metaanaly* or pooled analysis or (systematic* adj2 review*) or published studies or published literature or medline or embase or data synthesis or data extraction or cochrane).ti,ab.	292102
50	((health technolog* or biomedical technolog*) adj2 assess*).ti,ab.	3668
51	or/44-50	351931
52	3 and (10 or 15) and (43 or 51)	132
53	limit 52 to english language	120
54	limit 53 to yr="2000 -Current"	106
55	36 or 54	316
56	remove duplicates from 55	245

Cochrane Library

Line #	Terms	Results
#1	MeSH descriptor: [Heart Failure] explode all trees	4860
#2	((cardia? or heart) next (decompensation or failure or incompetence or insufficiency)) or cardiac stand still or ((coronary or myocardial) next (failure or insufficiency)):ti,ab,kw (Word variations have been searched)	9323
#3	Enter terms for search #1 or #2	9328
#4	MeSH descriptor: [Catheterization, Swan-Ganz] this term only	119
#5	pulmonary artery next (catheter? or catheteriz* or catheteris*):ti,ab,kw or Swan-Ganz next (catheter? or catheteriz* or catheteris*):ti,ab,kw (Word variations have been searched)	174
#6	#4 or #5	244
#7	MeSH descriptor: [Monitoring, Physiologic] this term only	1688
#8	invasive near/2 monitoring:ti (Word variations have been searched)	17
#9	#7 or #8	1698
#10	#3 and (#6 or #9)	58 from 2000 to 2012

4 DARE; 2 HTA

CRD

Line	Search	Hits
1	MeSH DESCRIPTOR Heart Failure EXPLODE ALL TREES IN DARE,HTA	345
2	(((cardia? OR heart) ADJ (decompensation OR failure OR incompetence OR insufficiency)) OR cardiac stand still OR ((coronary OR myocardial) ADJ (failure OR insufficiency))):TI IN DARE, HTA FROM 2000 TO 2012	203
3	#1 OR #2	375
4	MeSH DESCRIPTOR Catheterization, Swan-Ganz IN DARE,HTA	11
5	(pulmonary artery ADJ (catheter? OR catheteriz* OR catheteris*)):TI OR (Swan-Ganz ADJ (catheter? OR catheteriz* OR catheteris*)):TI IN DARE, HTA FROM 2000 TO 2012	9
6	#4 OR #5	14
7	MeSH DESCRIPTOR Monitoring, Physiologic IN DARE,HTA	93
8	(invasive ADJ2 monitoring):TI IN DARE, HTA FROM 2000 TO 2012	3
9	#7 OR #8	95
10	#3 AND #6	0
11	#3 AND #9	7

7=2000 current (2 HTA; 5 DARE)

Appendix 2: GRADE Tables

Table A1: GRADE Evidence Profile for the Comparison of PAC and Clinical Assessment

No. of Studies (Design)	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Upgrade Considerations	Quality
Mortality (6 months)							
1 (RCT)	No serious limitations	Not applicable	Serious limitations (–1)[a]	No serious limitations	Undetected	None	⊕⊕⊕ Moderate
Device-related complications							
1 (RCT)	No serious limitations	Not applicable	Serious limitations (–1)[a]	No serious limitations	Undetected	None	⊕⊕⊕ Moderate

Abbreviations: PAC, pulmonary artery catheter; RCT, randomized controlled trial.
[a]Generalizability concern, given that only patients in equipoise were included in the trial. Study stopped early due to safety and efficacy concerns.

Table A2: Risk of Bias Among Randomized Controlled Trials for the Comparison of PAC and Clinical Assessment[a]

Author, Year	Allocation Concealment	Blinding	Complete Accounting of Patients and Outcome Events[a]	Selective Reporting Bias[a]	Other Limitations[a]
Binanay et al., 2005 (11)	No limitations[b]	No serious limitations[c]	No limitations[d]	No limitations	No serious limitations[e]
Harvey et al., 2005 (10)	No limitations[b]	No serious limitations[c]	No limitations[d]	No limitations	No serious limitations[f]

Abbreviations: PAC, pulmonary artery catheter; RCT, randomized controlled trial.
[a]Mortality and complications.
[b]Central randomization via telephone.
[c]No blinding; however, the objective outcomes used may be less likely to be affected by lack of blinding.
[d]Low percentage of losses to follow-up (< 4.2%); intention-to-treat analysis performed.
[e]Study terminated early due to safety concerns and unlikelihood of significant benefit.
[f]Sample size recalculated during the study in order to account for a higher severity of patients included.

References

(1) Arnold JM, Liu P, Demers C, Dorian P, Giannetti N, Haddad H et al. Canadian Cardiovascular Society consensus conference recommendations on heart failure 2006: diagnosis and management. Can J Cardiol. 2006 Jan;22(1):23-45.

(2) Nieminen MS, Bohm M, Cowie MR, Drexler H, Filippatos GS, Jondeau G et al. Executive summary of the guidelines on the diagnosis and treatment of acute heart failure: the Task Force on Acute Heart Failure of the European Society of Cardiology. Eur Heart J. 2005 Feb;26(4):384-416.

(3) Shah MR, O'Connor CM, Sopko G, Hasselblad V, Califf RM, Stevenson LW. Evaluation Study of Congestive Heart Failure and Pulmonary Artery Catheterization Effectiveness (ESCAPE): design and rationale. Am Heart J. 2001;141(4):528-35.

(4) Husain S, Pamboukian SV, Tallaj JA, McGiffin DC, Bourge RC. Invasive monitoring in patients with heart failure. Curr Cardiol Rep. 2009 May;11(3):159-66.

(5) Health Canada Drugs and Health Products. Medical devices active licences [Internet]. [updated 2012; cited 2012 Oct 1]. Available from: http://www.hc-sc.gc.ca/dhp-mps/md-im/licen/index-eng.php

(6) Guyatt GH, Oxman AD, Vist G, Kunz R, Brozek J, Alonso-Coello P et al. GRADE guidelines: 4. Rating the quality of evidence—study limitations (risk of bias). J Clin Epidemiol. 2011 Apr;64(4):407-15.

(7) Guyatt GH, Oxman AD, Schunemann HJ, Tugwell P, Knottnerus A. GRADE guidelines: a new series of articles in the Journal of Clinical Epidemiology. J Clin Epidemiol. 2011 Apr;64(4):380-2.

(8) Shah MR, Hasselblad V, Stevenson LW, Binanay C, O'Connor CM, Sopko G et al. Impact of the pulmonary artery catheter in critically ill patients: meta-analysis of randomized clinical trials. JAMA. 2005;294(13):1664-70.

(9) Goodman, C. Literature searching and evidence interpretation for assessing health care practices. Stockholm, Sweden: Swedish Council on Technology Assessment in Health Care; 1996. 81 p. SBU Report No. 119E.

(10) Harvey S, Harrison DA, Singer M, Ashcroft J, Jones CM, Elbourne D et al. Assessment of the clinical effectiveness of pulmonary artery catheters in management of patients in intensive care (PAC-Man): a randomised controlled trial. Lancet. 2005 Aug 6;366(9484):472-7.

(11) Binanay C, Califf RM, Hasselblad V, O'Connor CM, Shah MR, Sopko G et al. Evaluation study of congestive heart failure and pulmonary artery catheterization effectiveness: the ESCAPE trial. JAMA. 2005;294(13):1625-33.

(12) Jessup M, Abraham WT, Casey DE, Feldman AM, Francis GS, Ganiats TG et al. 2009 focused update: ACCF/AHA Guidelines for the Diagnosis and Management of Heart Failure in Adults: a report of the American College of Cardiology Foundation/American Heart Association Task

Force on Practice Guidelines: developed in collaboration with the International Society for Heart and Lung Transplantation. Circulation. 2009 Apr 14;119(14):1977-2016.

(13) Dickstein K, Cohen-Solal A, Filippatos G, McMurray JJ, Ponikowski P, Poole-Wilson PA et al. ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure 2008: the Task Force for the Diagnosis and Treatment of Acute and Chronic Heart Failure 2008 of the European Society of Cardiology. Developed in collaboration with the Heart Failure Association of the ESC (HFA) and endorsed by the European Society of Intensive Care Medicine (ESICM). Eur Heart J. 2008 Oct;29(19):2388-442.

Health Quality Ontario
130 Bloor Street West, 10th Floor
Toronto, Ontario
M5S 1N5
Tel: 416-323-6868
Toll Free: 1-866-623-6868
Fax: 416-323-9261
Email: EvidenceInfo@hqontario.ca
www.hqontario.ca