A Review of Interventions and System Changes to Improve Time to Reperfusion for ST-Segment Elevation Myocardial Infarction

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OBJECTIVE: Identify and describe interventions to reduce time to reperfusion for patients with ST-segment elevation myocardial infarction (STEMI).

DATA SOURCE: Key word searches of five research databases: MEDLINE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), EMBASE, Web of Science, and Cochrane Clinical Trials Registry.

INTERVENTIONS: We included controlled and uncontrolled studies of interventions to reduce time to reperfusion. One researcher reviewed abstracts and 2 reviewed full text articles. Articles were subsequently abstracted into structured data tables, which included study design, setting, intervention, and outcome variables. We inductively developed intervention categories from the articles. A second researcher reviewed data abstraction for accuracy.

MEASUREMENTS AND MAIN RESULTS: We identified 666 articles, 42 of which met inclusion criteria. We identified 11 intervention categories and classified them as either process specific (e.g., emergency department administration of thrombolytic therapy, activation of the catheterization laboratory by emergency department personnel) or system level (e.g., continuous quality improvement, critical pathways). A majority of studies (59%) were single-site pre/post design, and nearly half (47%) had sample sizes less than 100 patients. Thirty-two studies (76%) reported significantly lower door to reperfusion times associated with an intervention, 12 (29%) of which met or exceeded guideline recommended times. Relative decreases in times to reperfusion ranged from 15 to 82% for door to needle and 13–64% for door to balloon.

CONCLUSIONS: We identified an array of process and system-based quality improvement interventions associated with significant improvements in door to reperfusion time. However, weak study designs and inadequate information about implementation limit the usefulness of this literature.

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INTRODUCTION

Acute myocardial infarction (AMI) accounts for 210,000 deaths in the US annually.[1] Patients admitted with ST-segment elevation myocardial infarction (STEMI) suffer the highest mortality rates, at 12–18%,[2,3] and constitute 30–45% of AMIs.[1] Emergent reperfusion therapies, such as thrombolysis and percutaneous coronary intervention (PCI), can halve mortality rates among patients with STEMI.[2,4–9] Guidelines from the American College of Cardiology and American Heart Association (ACC/AHA) call for thrombolysis within 30 minutes of hospital arrival ("door to needle time") or PCI within 90 minutes of hospital arrival ("door to balloon time ").[10]

The effectiveness of emergent cardiac reperfusion is highly time dependent[7,11,12] and studies have found that hospitals in the US fail to meet timeliness standards for two thirds of STEMI patients.[2,13,14] Achieving timely reperfusion is a major objective among professional and interest groups[10] and performance indicators for timely reperfusion are now publicly reported by The Joint Commission.[13,15]

The research literature describes a wide array of interventions to improve the timeliness of reperfusion; however, information about which interventions have overall demonstrated effectiveness in clinical practice is limited. A recent review of interventions to reduce time to reperfusion[16] focused exclusively on interventions to improve door to balloon times, yet only 20% of hospitals are equipped to perform primary PCI.[10] We conducted a review of all published interventions to improve timely reperfusion for patients presenting to emergency departments with STEMI. The purpose of this review was to describe and classify interventions to reduce door to reperfusion time, and summarize the current evidence base for each.

METHODS

Literature Search

We conducted a key word search of 5 library databases using identical search terms. These databases included: MEDLINE, Cumulative Index to Nursing and Allied Health Literature

(CINAHL), EMBASE, Web of Science, and the Cochrane Clinical Trials Registry. Publications available through April 2007 were included. The search was limited to studies of human subjects and English language publications. Conference abstracts were excluded, and there was no hand searching of reference lists.

The search criteria were developed through consultation and discussion among the authors and investigators affiliated with the VA Ischemic Heart Disease Quality Enhancement Research Initiative based on the researchers' experiences with relevant published literature. Several of the key search terms include "*ST elevation myocardial infarction*"; "*door to reperfusion" or "door to needle" or "door to balloon*"; and *reduce or decrease or compare or improve or quality.* The full list of general search terms that were used in each of the research databases are listed at the top of Figure 1.

Article Review and Categorization

One author (KAM) reviewed all study abstracts to determine whether they met the following inclusion criteria of studies that: (1) specifically examined either thrombolytic therapy or primary PCI as a treatment; (2) patient population included STEMI; (3) assessed an explicit quality improvement intervention to reduce time to reperfusion; (4) had timeliness of reperfusion as an endpoint; (5) reported absolute changes in time to reperfusion.

Two authors (KAM and AES) reviewed and categorized the remaining abstracts. Study categories were based on intervention type and whether the intervention occurred at the process or system level within the facility. At this point in the review, pre-hospital interventions were excluded because in the majority of these studies, the intervention was outside the control of an individual facility. These categories, further described in the "Results", were inductively developed based on labels and descriptions in the articles.

Full Text Review and Article Abstraction

Two authors (KAM and CDH) reviewed the full text of the remaining articles. One author (KAM) abstracted defined variables from the remaining articles into data tables. These variables were selected because of their impact on the validity and/or reliability of each study's findings. These variables included: sample size (both intervention and comparison groups), study design, setting, intervention category, study details, and reported measures of the door-to-reperfusion times for the study and comparison groups. The data tables were reviewed and edited by a second author (CDH), and the team reached consensus on all disagreements.

To classify study designs, we adapted published typologies from the Closing the Quality Gap literature review series[17] and work by Bauer and colleagues.[18]

Analysis Strategy

Our analysis strategy was descriptive. We inductively defined intervention categories and abstracted standardized variables. We then summarized abstracted data on research methods, settings, and outcomes within and among intervention categories.

RESULTS

Literature Review

The key word searches identified 666 articles. Of the original articles, 547 (82%) were excluded based on abstract review because they did not meet 1 of 5 broad inclusion criteria. Among the remaining 119 articles, 53 (45%) were eliminated because the intervention targeted pre-hospital care such as diagnosis and treatment of patients with STEMI by emergency medical services. Seven (11%) of the remaining 66 articles were excluded because they were not full-length publications. The full text review revealed an additional 17 (26%) articles that did not meet the inclusion criteria or involved pre-hospital interventions, leaving a final total of 42 articles. The interrater agreement was good (κ=0.75)[19] and disagreements regarding article inclusion were adjudicated by the investigator group. The literature search and article selection process is summarized in the flow chart in Figure 1.

Study Designs and Characteristics

Publications spanned from 1990 to 2007, with roughly half appearing since 2002. In terms of study design, 30 were pre/post, 7 used controls, 4 used a combination of pre/post and controls, and 1 used an interrupted time series. Seven of the 42 studies (17%) were multisite, 3 using controls[20–22] and four using a pre/post design.[23–26] One single-site study used an interrupted times series design.[27] Two studies used data from the National Registry of Myocardial Infarction (NRMI).[27,28] Less than half of the studies (47%) had a sample size larger than 100 patients.[27,29–33]

The objective of this review is to describe and categorize interventions to reduce door-to-reperfusion times. While meta-analysis was feasible for several intervention categories, we felt that generating pooled estimates was beyond the scope of this review.

Intervention Categories

Among the 42 studies, we classified interventions into 11 categories broadly divided into 2 groups (Table 1). The first group comprised specific process changes: (1) a fast track or direct cardiac care unit admission policy for patients with STEMI, (2) delivering thrombolytic therapy in the emergency department, (3) delegating the administration of thrombolytic therapy to nurses, (4) direct activation of the catheterization laboratory by emergency department personnel, (5) policy changes, and (6) use of technology (Tables 2 and 3). The second group of interventions comprised system level interventions not specific to a disease condition or hospital department: (1) continuous quality improvement, (2) clinical staff education, (3) audit and feedback, (4) critical pathways, and (5) multifaceted, guideline-based initiatives to improve care for patients with AMI (Tables 4 and 5). While these system level interventions were specifically used to improve timely reperfusion, they are applicable to a wide range of performance issues. Below, we briefly summarize the research findings for each category. Unless otherwise noted, the studies were pre/post designs. We

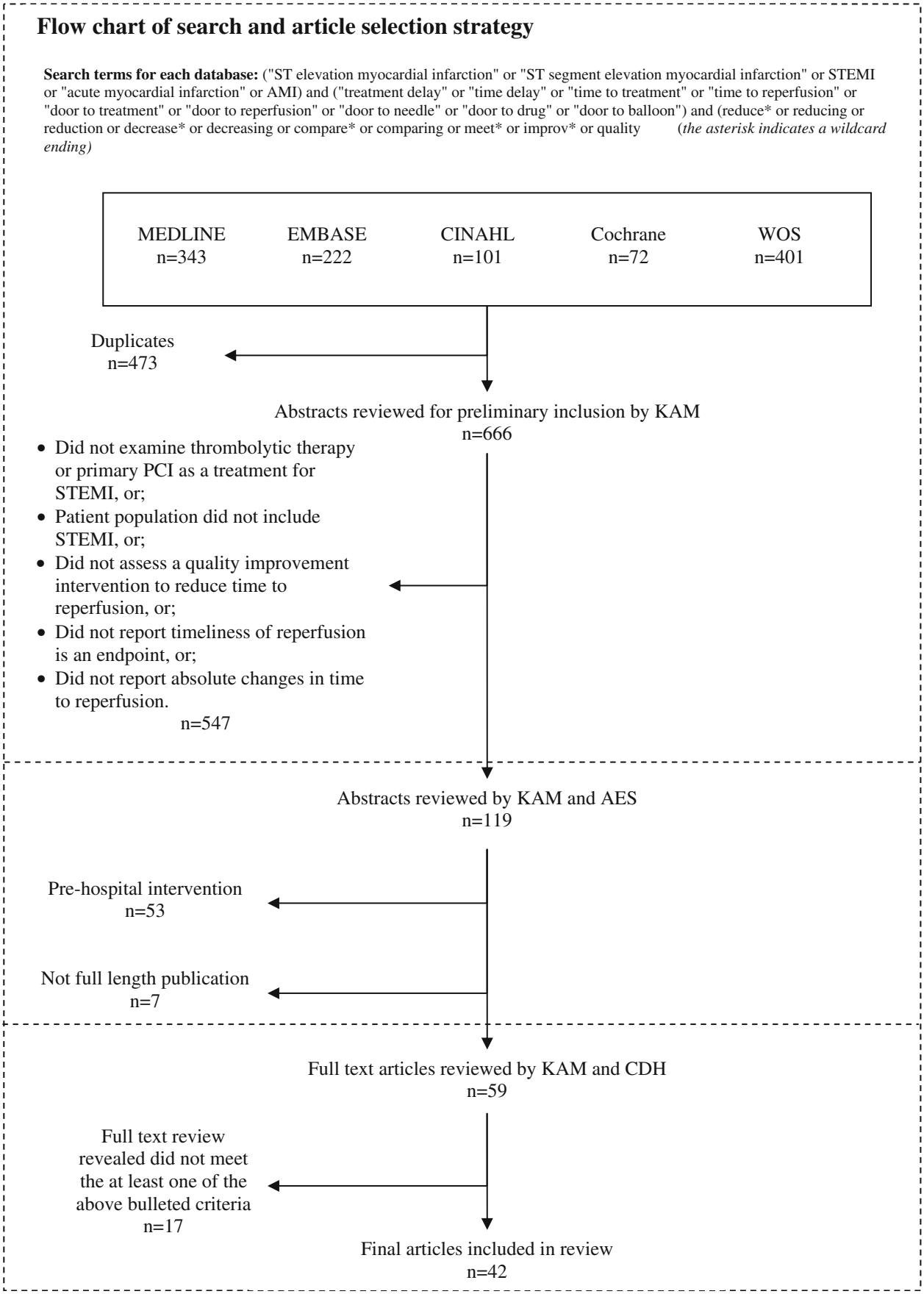

Figure 1. Figure flow chart of search and article selection strategy.

Table 1. Intervention Categories

Process level interventions	Articles studying this intervention
A number of studies examined modifications to the delivery of care process after the patient presents to the emergency department. These are direct attempts to reduce the time from admission to reperfusion by cutting delay from specific steps in the process of care.	
Fast track or direct admission to CCU	
Fast track of direct admission to the CCU refers to interventions examining the effects of having a triage nurse or chest pain nurse specialist identify patients with a potential STEMI and send them through an expedited process of care.	Table 2: MacCllum 1990; Thomas 1997; Kelion 1998
ED thrombolytics	
ED thrombolytics refers to an intervention in which the storage and administration of thrombolytics is moved to the ED to eliminate the delay associated with transferring the patient to the CCU for thrombolytics.	Table 2: Kendall 1996; Chan 1998; Edhouse 1999; Hourigan 2000; Heath 2003; Corfield 2004; Irwani 2004; McLean 2004; Lane 2005
Nurse thrombolytics	
Nurse thrombolytics refers to the training of nurse specialists to administer thrombolytics, targeting the time lags associated with waits for physician and cardiologist involvement.	Table 2: Somaroo 1999; Lloyd 2000; Wilmhurst 2000; Qasim 2002; Kuppswamy 2006
Use of technology	
Use of technology in this review refers to the use of a fax transmission of ECG to an offsite cardiologist or a decision support computer program for administration of thrombolytics in the ED.	Table 2: Kellett 2001; Chongtham 2006
ED activation of cath lab	
ED activation of the cath lab refers to an intervention to bypass the initial cardiology consultation and transferring the responsibility for diagnosis and activation of the cath lab to ED physicians to eliminate the delay associated with waiting for a cardiology consultation.	Table 3: Thatcher 2003; Zarich 2004; Jacoby 2005
Policy changes	
Policy changes in this review refers to hospital policy changes including the development of a transfer protocol or the initiation of PCI at facilities without onsite surgical backup.	Table 3: Sanborn 2004; Wharton 2004; Henry 2005; Brown 2006
System level interventions	
The system level interventions generally are interventions that occur upstream from the immediate emergency department to effect more comprehensive system change.	
Continuous Quality Improvement (CQI)	
CQI in health care refers to process improvement based on 5 key principles: 1) the focus is on systems and processes as opposed to individuals; 2) problem solving is structured and based on formal statistical analysis; 3) cross functional staff teams make changes; 4) staff are empowered to identify problems and take action to improve care; and 5) the focus is on patient-centered care.	Table 4: Bharat 1998; Gilutz 1998; Guidry 1998; Bonetti 2000; Saturno 2000 Table 5: Caputo 1997; Caputo 2005

Table 1. (continued)

System level interventions	Articles studying this intervention
(Bonetti, Waeckerlin et al. 2000; Saturno, Felices et al. 2000) CQI frequently employs tools such as *X*–charts and fishbone diagrams as part of the process of assessing process delays. Because CQI can indicate a number of different interventions, if the authors refer to their study as CQI, then we consider it a CQI intervention.	
Education	
Clinician education refers to an explicit intervention to disseminate information about guidelines or policies to clinical staff, or to otherwise increase awareness of timely reperfusion therapy for STEMI.	Table 4: Porter 1995; Kinsman 2007
Audit and feedback	
Audit and feedback refers to a cycle of data collection on care processes and outcomes reported to clinicians to improve performance on those processes and outcomes.	Table 4: Owen 2000
Critical pathways	
Critical pathways refers to the standardization of care processes to eliminate undesirable variation. (Cannon, Hand et al. 2002) Features include risk-specific pathways, preprinted forms or web based tools to improve provider access to pathways, and staff and clinician education regarding guidelines or pathways.	Table 4: Maxey 1997; Cannon 1999; Pelliccia 2004 Table 5: Bestul 2004; Pelliccia 2004
Multifaceted	
Multifaceted refers to the implementation of multiple interventions simultaneously as an integrated strategy to effect change.	Table 4: Senior 1998; Mehta 2002 Table 5: Mehta 2002

have included an online Appendix that provides further details of the studies.

Process Interventions

Studies of process interventions in emergency departments are detailed in Tables 2 and 3. The majority of the process intervention studies (73%) focused on reducing door-to-needle time (Table 2).

Fast Track or Direct Admission to the Cardiac Care Unit. Three studies assessed a fast track policy or policy of direct admission to the cardiac care unit for patients with STEMI (Table 2).[34–36] As an example of such an intervention, 1 study created a fast track program with a direct phone line to the cardiac care unit and 2 reserved beds for general practitioners to admit patients directly.[35]

All 3 studies assessed door-to-needle times and reported a relative decrease ranging from 41 to 81%, with intervention group times ranging from 13.5 to 19 minutes.

Table 2. Process Interventions to Reduce Door-to-Needle Times

Authors	Sample size*	Study design	Setting†	Intervention	DTN comparison in minutes‡	DTN intervention in minutes‡
MacCallum et al. 1990[36]	83 total C) 42 pre I) 39 post	Pre/post	UK; hospital	Fast track	29 median range (2,100)‖	17 median range (2,99)‖
Thomas et al. 1997[35]	96 total C) 85 others I) 11 fast track to CCU	Non–equivalent controls	UK; hospital	General practitioner fast track to CCU	74 median range (22, 95)¶	13.5 median range (5,30)¶
Kelion et al. 1998[34]	68 total C) 27 pre I) 41 post	Pre/post	UK; teaching hospital	Direct admission to CCU	61 (70)‖	19 (20)‖
Kendall et al. 1996[41]	Unknown total C) N/A pre I) 182 post	Pre/post	UK; hospital	ED administration of thrombolytic therapy	110 median‖	38 median‖
Chan et al. 1998[37]	257 total C) 195 CCU I) 62 ED	Non–equivalent controls	Hong Kong; hospital	ED administration of thrombolytic therapy	81§,¶	25§,¶
Edhouse et al. 1999[38]	153 total C1) 43 transferred to CCU, treated by ED staff C2) 29 transferred to CCU, treated by CCU staff					
	C3) 13 admitted directly to CCU I) 56 thrombolytics in ED	Non– equivalent controls	UK; teaching hospital	ED administration of thrombolytic therapy	C1) 54 median IQR (40,710)‖ C2) 82 median IQR (55,118)‖ C3) 80 median IQR (69,113)‖	42.5 median IQR (28, 51)‖
Hourigan et al. 2000[39]	189 total C) 89 CCU I) 100 ED	Pre/post	Australia; teaching hospital	ED administration of thrombolytic therapy	80 median 95% CI (70,89)‖	37 median 95% CI (33,44)‖
Corfield et al. 2004[32]	643 total C) 320 pre I) 323 post	Pre/post	Scotland; district general hospital; 450 beds; urban/rural	ED administration of thrombolytic therapy	64 median IQR (46,95)‖	35 median IQR (25, 65)‖
Irwani et al. 2004[40]	196 total C) 118 CCU I) 78 ED C) 118 CCU	Pre/post	Singapore; teaching hospital; 75,000 ED patients annually	ED administration of thrombolytic therapy	60 median‖	29 median‖
McLean et al. 2004[43]	74 total C) 35 pre I) 39 post	Pre/post	Scotland; regional hospital; 40,000 ED patients annually; urban /rural	ED administration of thrombolytic therapy	80 median range (20,235)‖	22 median range (9,80)‖
Lane et al. 2005[42]	154 total C) 62 CCU I1) 39 ED intervention I2) 53 ED post intervention	Pre/post and non-equivalent controls	Ireland; district general hospital	ED administration of thrombolytic therapy	62 median IQR (39,93)¶	I1) 21 median IQR (12.5,45.5)¶ I2) 20 IQR (13.5,35)¶
Somauroo et al. 1999[45]	86 total C1) 41 ED physician administered, pre C2) 203 ED physician administered, post I) 45 nurse administered, post	Pre/post and non-equivalent controls	UK; university hospital	ED administration of thrombolytic therapy	C1) 66 median IQR (60,92)‖ C2) 65 median IQR (51,94)‖	I) 30 median IQR (20,40)‖
Lloyd et al. 2000[47]	151 total C) 73 pre I) 78 post	Pre/post	UK; district general hospital; 450 bed; urban/rural	Nurse administration of thrombolytic therapy in the CCU	60 median IQR (42,110)‖	30 median IQR (20,61)‖
Wilmshurst et al. 2000[27]	799 total C) 463 pre I) 336 post	Interrupted time series	UK; district general hospital; 250–300 AMI patients annually	Nurse administration of thrombolytic therapy in the CCU	median range of 7 periods preintervention 50–58‖	median range of 4 periods post intervention 25–30‖

(*continued on next page*)

Table 2. (continued)

Authors	Sample size*	Study design	Setting†	Intervention	DTN comparison in minutes‡	DTN intervention in minutes‡
Qasim et al. 2002[31]	410 total C1a) 160 pre C1b) 157 fast track to CCUI1) 93 post C2) 69 physician thrombolytics I2) 24 nurse thrombolytics	Pre/post and non-equivalent controls	UK; district general hospital; 350 beds; 5 CCU beds	Nurse administration of thrombolytic therapy in the CCU	C1a) 45 median range (5,300)¶ C1b) 40 median Range (5,180)¶ C2) 20 median range (5,70)¶	I1) 15 median range (5,70)¶ I2) 15 medianrange (5,30)¶
Heath et al. 2003[44]	91 total C) 48 CCU I) 43 ED	Non-equivalent controls	UK hospital	Nurse administration of thrombolytic therapy in the CCU	56 median IQR (34,79.5)‖	23 median IQR (17,32)‖
Kuppuswamy et al. 2006[46]	115 total C1) 47 ED staff I1) 68 nurse C2) 64 t-PA I2) 51 bolus	Pre/post and non-equivalent controls	UK; university hospital; urban	Nurse administration of thrombolytic therapy in the CCU	Nurse t-PA 27.2 median 95%CI (21,33.4)‖ ED t-PA 39.6 mean	Nurse bolus 16.9 median 95%CI (13.5,20.4)‖ ED bolus 40 mean
Chongtham et al. 2006[50]	75 total C1) 25 transferred to tertiary C2) 25 admitted to tertiary I) 25 faxed ECG	Non-equivalent controls	India; one primary care civil hospital; one teaching hospital	Use of technology: fax transmission to offsite cardiologist	C1) 121.8 (48.7)‖ C2) 22.7 (9.2)‖	67.1 (18.2)‖
Kellett 2001[33]	894 total C) 262 pre I) 632 post	Pre/post	Ireland; rural; 35 acute medical beds, 4 bed CCU admitting 2500 patients annually	Use of technology: decision support computer program for thrombolytics	88§,‖	67§,‖

IQR interquartile ratio, CI confidence interval, AMI acute myocardial infarction, ED emergency department, CCU coronary care unit
*Sample size is broken into: *C* comparison or control group and *I* Intervention group. Multiple comparison or intervention groups are differentiated by numbers.
†*Setting details include whatever description was provided by authors.*
‡*Parameters are those reported by the author and are indicated after each estimate. Means should be assumed when (SD) is present.*
§*Authors gave no indication as to whether the results were means or medians.*
‖ *The difference is significant at p<0.05*
¶*Authors did not report significance*

Administering Thrombolytics in the Emergency Department. Eight studies tested the effect of moving the administration of thrombolytics from the cardiac care unit to the emergency department (Table 2).[32,37–43] Two studies were conducted at hospitals that continued to admit some patients to the cardiac care unit to receive thrombolytics, thus comparisons were both pre/post intervention analysis and between delivery time in the emergency department and the cardiac care unit.[37,38] Three studies also included an educational component to the intervention.[32,37,41]

Relative decreases in door-to-needle times for moving thrombolytic therapy to the emergency department ranged from 45 to 72%, with intervention group times ranging from 20 to 42.5 minutes.

Nurse-administered Thrombolytics. Six studies tested the effectiveness of training a nurse to administer thrombolytic therapy, either in the emergency department[44–46] or in the cardiac care unit (Table 2).[27,31,47] Three studies used non-equivalent controls comparing nurse administered thrombolytics to physician-administered thrombolytics.[31,44,45] One study was an interrupted time series.[27]

All studies found a relative decrease in door-to-needle time ranging from 38 to 67%, with delivery in the emergency department associated with shorter door-to-needle times (ranging from 16.9 to 30 minutes) compared to delivery in the cardiac care unit (ranging from 25 to 40 minutes).

Emergency Department Activation of the Catheterization Laboratory. Two studies assessed the activation of the catheterization laboratory team directly by emergency department personnel without consulting with an attending cardiologist (Table 3).[48,49] Both were retrospective chart reviews and reported a relative reduction in door to balloon times of 24% [48] and 30%.[49]

Policy Changes. Four studies changed hospital policy; three began performing PCI without onsite surgical backup;[21,28,29] and 1 developed a protocol to facilitate the transfer of patients with STEMI to a primary PCI capable hospital (Table 3).[24] The study testing a transfer protocol found that door-to-balloon times were cut nearly in half to a median time of 98 minutes.[24]

One study used contemporary controls comparing onsite primary PCI without surgical backup to transfer to a primary PCI-capable facility with surgical backup and observed a 37% relative decrease in median door-to-balloon time.[29] The remaining 2 studies evaluated onsite PCI without surgical backup using National Registry of Myocardial Infarction (NRMI) registry data.[21,28] One study showed mean door-to-balloon times were shorter in PCI-only facilities compared to transferring to

Table 3. Process Interventions to Decrease Door-to-Balloon Times

Authors	Sample size*	Study design	Setting†	Intervention	DTN comparison in minutes‡	DTN intervention in minutes‡
Thatcher et al. 2003[49]	180 total C) 99 pre I) 81 post	Pre/post	US; community hospital	ED physicians activate cath lab	88 median 95%CI (80,96)‖	61 median 95% CI (57,70)‖
Zarich et al. 2004[25]	158 total C) 91 pre I) 67 post	Pre/post	US; university affiliated community teaching hospital col laborated with six regional hospitals	ED physicians activate cath lab	141.3 (42.2)‖ 132 median	95.1 (30)‖ 93 median
Jacoby et al. 2005[48]	44 total C) 20 pre I) 24 post	Pre/post	US; community teaching hospital; 55,000 ED patients annually	ED physicians activate cath lab	118§,‖	89§,‖
Sanborn et al. 2004[20]	C1) 817 patients at non-PCI capable facilities C2) 1057 patients at PCI only facilities I) 24,840 patients at PCI and surgical back up facilities	Non-equivalent controls	NRMI 3 and 4	Policy changes: PCI without surgical backup	C1) 104 mean 95%CI (101,108)‖ C2) 116 mean 95%CI (112,119)‖	119 95% CI (118,120)‖
Wharton, Jr. et al. 2004[21]	571 total C) 71 transfer I) 500 no surgery on site	Contemporary controls	US; 19 hospitals	Policy changes: PCI without surgical backup	187 (75)‖ 166 median IQR (131,240)	120 (69)‖ 105 median IQR (80,139)
Henry et al. 2005[23]	27 total C) 5 pre I) 22 post	Pre/post	US; one 100 bed hospital and one 619 bed hospital 30 miles away	Policy changes: transfer protocol	192 median IQR (171,232)‖	98 median IQR (86,116)‖
Brown et al. 2006[28]	C) NRMI 2003 I) 50 patients in a rural hospital	Non-equivalent controls	US; 225 beds; rural	Policy changes: PCI without surgical backup	186§, ¶	67.66 (30.8)¶

IQR interquartile ratio, CI confidence interval, ED emergency department, CCU coronary care unit, NRMI National Registry of Myocardial Infarction
Sample size is broken into: C comparison or control group and I Intervention group. Multiple comparison or intervention groups are differentiated by numbers.
†Setting details include whatever description was provided by authors.
‡Parameters are those reported by the author and are indicated after each estimate. Means should be assumed when (SD) is present.
§*Authors gave no indication as to whether the results were means or medians.*
‖ *The difference is significant at p<0.05*
¶*Authors did not report significance*

primary PCI-capable facilities with surgical backup using data from NRMI 3 and 4. Despite this improved time to reperfusion, this study showed no differences in other quality of care indicators or adherence to ACC/AHA guidelines.[21] The other study found mean door-to-balloon time was 64% lower at a rural hospital conducting PCI without onsite surgical backup compared to average transfer times reported in NRMI 4.[28]

Use of Technology. Two studies assessed interventions that were based on new uses of technology (Table 2). In 1 study, a computerized decision support program for the administration of thrombolytic therapy decreased door-to-needle times by 24%.[33] The other study found that faxing ECG results from the emergency department to an offsite cardiologist decreased door-to-needle time significantly compared to transferring patients.[50]

System Level Interventions

Studies of system level interventions are detailed in Tables 4 and 5. Table 4 includes studies that assessed door-to-needle times and Table 5 includes studies that assessed door-to-balloon times.

Continuous Quality Improvement. Continuous quality improvement (CQI) is a cross-disciplinary, team-based approach designed to make systemic changes to care delivery processes. Seven studies evaluated CQI interventions, 2 to decrease door-to-balloon time (Table 5)[51,52] and 5 to decrease door-to-needle time (Table 4).[53–57] All 7 studies involved a series of steps to assess and reduce time delays. Two studies reported using CQI to develop a number of procedure or policy changes to decrease door-to-balloon time, including discouraging referring cardiologists from evaluating the patient until after PCI[51] and development of an on-call schedule for interventional cardiologists and support teams.[52] All studies reported significant relative decreases in door-to-reperfusion times ranging from 15 to 56% with door-to-balloon times ranging from 97 to 112 minutes and door-to-needle times ranging from 22.6 to 47.6 minutes after the intervention.

Clinical Staff Education. While studies frequently described provider education as auxiliary to the main intervention under study, 2 specifically identified education as the focus of the intervention (Table 4).[26,58] Only 1 study found a significant improvement in door-to-needle time by providing education to

Table 4. System Level Interventions to Decrease Door-to-Needle Times

Authors	Sample size*	Study design	Setting†	Intervention	DTN comparison in minutes‡	DTN intervention in minutes‡
Bharat et al. 1998[56]	78 total C) 46 pre I) 32 post	Pre/post	India; 850 bed hospital attached to the Tata Iron and Steel Co. Ltd.	CQI	48.9 mean‖	22.6 mean‖
Gilutz et al. 1998[55]	100 total C1) 40 pre C2) 27 during I) 33 post	Pre/post	Israel; tertiary hospital; 1000 beds; 160,000 ED patients annually	CQI	C1)61.8 (32.5) 50 median‖ C2) 57.7 (40.8) 45 median¶	47.6 (18.5) 42 median‖
Guidry et al. 1998[57]	349 total	Pre/post	US; university tertiary hospital; urban	CQI	46 median‖	36 median‖
Bonetti et al. 2000[53]	37 total C1) 16 before C2) 5 during I) 16 post	Pre/post	Switzerland; community hospital; 300 beds	CQI	C1) 57 (25.4)‖ C2) 24 (3.8)‖	32 (9)‖
Saturno et al. 2000[54]	76 total C) 46 I) 30	Pre/post	Spain; university hospital; 285 beds	CQI	59 median IQR (41, 88)¶	30 median IQR (25, 35)¶
Porter et al. 1995[58]	62 total C) 40 pre I) 22 post	Pre/post	New Zealand hospital	Education	66 (35) 59 median range (20–175)‖	52 (32) 40 median range (20–150)‖
Kinsman et al. 2007[26]	75 total C) 35 pre I) 40 post	Pre/post	Australia; 4 hospitals within the Loddon Mallee Region of Victoria	Education	67.7 (79.2) range (9,430)	60.5 (86.8) range (5, 450)
Owen et al. 2000[59]	85 total C) 36 pre I) 49 post	Pre/post	UK; district general hospital	Audit & feedback	32 median¶	27 median¶
Maxey 1997[60]	30 total C) 11 pre I) 19 post	Pre/post	US; 103 bed hospital	Critical pathways	65.5 (44) 64 median‖	28.8 (15) 25 median‖
Cannon et al. 1999[4]	62 total C) 9 pre I) 53 post	Pre/post	NA	Critical pathways	73 median‖	37 median‖
Pelliccia et al. 2004[30]	972 total C) 520 pre I) 452 post	Pre/post	Italy; large urban hospital	Critical pathways	35 (10)‖	25 (10)‖
Senior et al. 1998[63]	48 total C1) 20 1995 year C2) 18 1996 year I) 10 1997 year	Pre/post	Australia; level 4 district hospital; 21,700 ED patients in 1995	Multifaceted	C1) 85 median IQR (67,99)¶ C2) 52 median IQR (30, 111)¶	57 median IQR (26–95)¶
Mehta et al. 2002[24]	64 total C) 40 pre I) 24 post	Pre/post	US; 21 hospitals in Michigan	Multifaceted	39§	40 §

NA not applicable, IQR interquartile ratio, CI confidence interval, CQI continuous quality improvement, ED emergency department, CCU coronary care unit
* Sample size is broken into C)=comparison or control group and I)=Intervention group.
Multiple comparison or intervention groups are differentiated by numbers.
†*Setting details include whatever description was provided by authors.*
‡*Parameters are those reported by the author and are indicated after each estimate.*
Means should be assumed when (SD) is present.
§*Authors gave no indication as to whether the results were means or medians.*
‖ *The difference is significant at $p<0.05$*
¶*Authors did not report significance*

Table 5. System Level Interventions to Decrease Door-to-Balloon Times

Authors	Sample size*	Study design	Setting†	Intervention	DTN comparison in minutes‡	DTN intervention in minutes‡
Caputo et al. 1997[51]	52 total C) 19 pre I1) 17 post I2) 16 post	Pre/post	US; urban hospital	CQI	C1) 205 mean‖ C2) 119 mean‖	97 mean‖
Caputo et al. 2005[52]	91 total C) 45 pre I) 46 post	Pre/post	US; community hospital	CQI	132 (69.2)‖	112 (72)‖
Bestul et al. 2004[62]	175 total C) 89 pre I) 86 post	Pre/post	US; large university hospital	Critical pathways	108 median‖	91.5 median‖
Pelliccia et al. 2004[30]	972 total C) 520 pre I) 452 post	Pre/post	Italy; large urban hospital	Critical pathways	99 (20)‖	70 (15)‖
Mehta et al. 2002[24]	77 total C) 32 pre I) 45 post	Pre/post	US; 21 hospitals in Michigan	Multifaceted	130 mean	111 mean

IQR interquartile ratio, CI confidence interval, CQI continuous quality improvement, ED emergency department, CCU coronary care unit
*Sample size is broken into C)=comparison or control group and I)=Intervention group.
Multiple comparison or intervention groups are differentiated by numbers.
†Setting details include whatever description was provided by authors.
‡*Parameters are those reported by the author and are indicated after each estimate. Means should be assumed when (SD) is present.*
‖ *The difference is significant at $p<0.05$*

medical registrars to facilitate reperfusion for patients with STEMI.[58]

Audit and Feedback. A number of studies included an audit component to identify delays in their processes of care; however, only 1 used audit and feedback as the focus of their intervention (Table 4).[59] In this study, investigators disseminated guidelines and then performed a prospective audit to determine the effect on door-to-needle times. The results were subsequently disseminated and a follow-up audit was performed. This study reported a relative decrease in median door-to-needle times of 16%. However, the authors did not report enough information to determine whether the improvement was statistically significant.[59]

Critical Pathways. Four studies assessed critical pathways. Two addressed the delivery of thrombolytic therapy (Table 4)[60,61]; 1 addressed primary PCI (Table 5)[62]; and 1 addressed both therapies (Tables 4 and 5).[30] All studies reported statistically significant improvements. Relative decreases in door-to-needle time ranged from 29 to 61%, and were 15% and 29% for door-to-balloon time.

Multifaceted. While many of the studies evaluated interventions that consisted of more than 1 component,[32,37,41] 2 studies evaluated interventions that were multifaceted by design (Table 4).[25,63] One examined the implementation of the ACC Guidelines Applied in Practice (GAP) initiative focusing on both time to reperfusion and medication quality indicators in 21 Michigan hospitals.[25] The other adopted the following strategies as part of a multifaceted intervention: keeping the ECG machine and fax machine in the emergency department; keeping thrombolytics in the emergency department; clinical staff education; and allowing emergency department clinicians to initiate thrombolytics if a cardiologist was not available.[63] Neither study found significant changes in door-to-needle times.

DISCUSSION

We conducted this review to provide a foundation for developing evidence-based toolkits to improve timely reperfusion for patients with STEMI. We found a sizable literature addressing reperfusion timeliness and describing an array of process- and system-based quality improvement interventions. Overall, the research literature suggests there are a number of potentially effective interventions to improve door-to-reperfusion time. Thirty-two studies reported significantly lower door-to-reperfusion times associated with the intervention, and in 12 of those, the door-to-reperfusion time for the intervention group met or exceeded guideline specified times (30 minutes for thrombolytics and 90 minutes for PCI).

The process level interventions may be most useful to practitioners. Compared to the system level interventions, the 6 process level interventions entail distinct changes with high face validity. In particular, fast track or direct admission to the cardiac care unit and delivery of thrombolytics by nurses rather than physicians were associated with large decreases in door-to-needle times meeting the guideline recommendations. Similarly, direct activation of the catheterization laboratory by emergency department physicians, and policy changes to perform PCI without onsite surgical backup or to institute transfer protocols were associated with large decreases in door-to-balloon times and median door to balloon times that met or approached guideline recommended timeframes.

However, two factors limit the evidence provided by this literature. First, the strength of the evidence is modest because of the methodological weakness of the majority of studies. Twenty-nine of the 42 studies (69%) reviewed were single-site, pre/posttest evaluations without contemporary controls. Internal validity is a particular concern with pre/posttest designs because they do not control for secular time trends. In addition, studies with contemporary controls were generally comparing non-equivalent groups.

Second, few studies included important information regarding the implementation of the intervention. Such information may include changes in clinician and staff roles and relationships; formal policy changes; additional funding and personnel, and the cost effectiveness of the intervention. Furthermore, critical organizational factors, such as interventional cardiology capacity, transfer times to interventional hospitals, emergency department staffing levels, and AMI patient volumes were largely not described. This lack of detail is of particular concern in evaluating interventions in implementation research because the unit of intervention is the provider team or organization, and context is a likely confounder or effect modifier. In the context of the debate about the evidence base for clinical practices, this basic information about the clinical context of study findings has been ignored, leaving clinicians and managers in the field without essential information for determining which interventions might best fit their needs and capabilities.

Brevity imposed by peer-reviewed clinical journals may account for the insufficient detail in the reports, particularly with respect to detailed information necessary for implementation and replication in other sites. Furthermore, despite frequent calls in implementation research to explicitly describe a theoretical framework,[64,65] we found no explicit discussion and very little implicit discussion of the theoretical underpinnings or hypothesized mechanisms of action for any of the interventions. Elaboration of such aspects of the intervention could allow an assessment of multiple measures of the mechanism and thus provide stronger evidence for the intervention. Such information should be made available to interested parties in some manner, such as through on-line appendices, if not in the articles.

The weak design of these studies makes it difficult to endorse any of the quality improvement interventions reviewed. This is of concern given the high profile of performance measures and the strength of the evidence regarding the need to minimize time to reperfusion. The evidence available to guide decision-makers in how best to improve performance in this area is weak.

Limitations

This study had 4 principal limitations. First, our search was not exhaustive in that we limited it to studies published in English, we did not attempt to examine unpublished literature, and we did not perform any hand searching of reference lists. Second, we did not conduct quantitative analyses to determine a pooled effect size for each intervention. We felt that an exhaustive search and metaanalysis were beyond the scope of this review. Third, only 1 author performed the initial review of abstracts

resulting from the database searches. This preserved limited resources and we felt that it would not significantly compromise the objectivity of the review. Finally, the intervention categories we used were developed inductively and may have limited utility (or validity) beyond this sample of studies.

CONCLUSION

There is a critical need for well-designed multisite studies of promising interventions to improve both door-to-needle and door-to-balloon times. The prevalence of single-site studies makes it difficult to confidently recommend any quality improvement interventions to hospitals and health care systems attempting to improve reperfusion outcomes. Without evidence of the generalizability of these interventions, such studies are less than fully informative to decision makers who need sound evidence and replicable findings. Given the importance of high quality, timely care for patients with STEMI, conducting more robust studies should be a matter of some urgency.

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