ESC European Society of Cardiology

European Heart Journal - Quality of Care and Clinical Outcomes (2020) **0**, 1–7
doi:10.1093/ehjqcco/qcaa067

ORIGINAL ARTICLE

Adherence to quality indicators for ST-elevation myocardial infarction and its relation to mortality: a hospital network analysis from the Belgian STEMI database

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Received 19 January 2020; revised 24 March 2020; editorial decision 6 April 2020; online publish-ahead-of-print 17 September 2020

Aims To assess the adherence to established quality indicators (QIs) for ST-elevation myocardial infarction (STEMI) at the hospital-network level and its relation to outcome.

Methods and results The data of 7774 STEMI patients admitted to 32 STEMI networks during the period 2014–18 were extracted from the Belgian STEMI database. Five QIs [primary percutaneous coronary intervention use, diagnosis-to-balloon time (DiaTB) <90 min, door-to-balloon time (DoTB) <60 min, P2Y12 inhibitor and statin prescription at discharge, and a composite QI score ranging from 0 to 10] were correlated with in-hospital mortality adjusted for differences in baseline risk profile (TIMI risk score). The median composite QI score was 6.5 [interquartile range (IQR) 6–8]. The most important gaps in quality adherence were related to time delays: the recommended DiaTB and DoTB times across the different networks were achieved in 68% (IQR 53–71) and 67% (IQR 50–78), respectively. Quality adherence was better in networks taking care of more high-risk STEMI patients. The median in-hospital mortality among the STEMI networks was 6.4% (IQR 4.1–7.9%). There was a significant independent inverse correlation between the composite QI score and in-hospital mortality (partial correlation coefficient: -0.45, $P = 0.013$). Stepwise regression analysis revealed that among the individual QIs, prolonged DiaTB was the most important independent outcome predictor.

Conclusion Among established STEMI networks, the time delay between diagnosis and treatment was the most variable and the most relevant prognostic QI, underscoring the importance of assessing quality of care throughout the whole network.

Keywords Quality indicator • STEMI • Primary PCI

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Introduction

The current guidelines for the management of ST-segment elevation myocardial infarction (STEMI) recommend primary percutaneous coronary intervention (pPCI) as the preferred reperfusion strategy if it can be conducted in a timely manner by an experienced catheterization team.[1,2] However, because of logistical restraints, pPCI can only be performed in <50% of hospitals.[3] In Belgium, PCI can be performed in ~50% of the hospitals. Against this background, STEMI networks were established with prearranged protocols for rapid transfer of patients between community hospitals and pPCI centres.[4–7] The introduction of networks improved the care process and reduced health care disparities. Reports from the USA and Europe, where hospitals implement the key care processes within a STEMI network, showed a reduction in reperfusion delays, an increase in the proportion of patients receiving primary PCI and a reduction in in-hospital mortality.[8–11] However, between and within European country variation in the delivery of care and outcomes for acute myocardial infarction suggests that the full potential to reduce the burden of cardiovascular disease has not been realized.[12] Recently, the Association for Acute CardioVascular Care (ACCA) of the European Society of Cardiology (ESC) published a report that validated specific quality indicators (QIs) for acute myocardial infarction based on European guidelines.[13] Recent large-scale national studies have shown a clear correlation between adherence to those QIs and mortality.[9,14–16] In all of these studies, the analysis was patient/hospital-based but not network-based. Analysis at the network level instead of at the hospital level will allow for a global assessment of the quality of care across a chain of caregivers from different hospitals belonging to a network.

Moreover, in the perspective of accreditation programmes imposed by the government, aggregated quality data and aggregated outcome data of hospital networks are often requested and reported.

Accordingly, the present report describes the adherence to QIs for the different STEMI networks in Belgium and the relationship between this adherence and mortality. In addition, the study sought to identify the most important gaps in network performance that affect outcome and that may help rank established QIs for STEMI management.

Methods

Study population and data collection

Data were extracted from the Belgian National STEMI Database, a prospective, observational database containing the demographics, practice patterns, and health outcomes of unselected patients with STEMI.[17] ST-elevation myocardial infarction patients were defined as patients with symptoms suggestive of ACS, a significant ST-T segment deviation [i.e. an ST elevation of >0.1 mV in 2 or more continuous electrocardiogram (ECG) leads, a new left bundle branch block, or an ST-segment depression of 0.1 mV or greater in 2 of the precordial leads V1–V4] and elevated biomarkers for myocardial necrosis.

The data were collected for consecutive STEMI patients between 1 October 2014 and 31 December 2018. The initial database consisted of 43 networks that enrolled 8442 STEMI patients. After exclusion of networks with fewer than 20 completed patient files, the final study population consisted of 7774 STEMI patients admitted to 32 networks. A PCI network was defined as network with a minimum of one PCI-capable hospital surrounded by hospitals without PCI capacities that send their STEMI patients to the PCI-capable hospital according to a prearranged transfer protocol. The median number of hospitals per network was two (range 2–6). The median number of enrolled patients per network was 211 (range 63–592). The average distance between the PCI-capable hospital and the referring hospitals was 20 ± 20 km (range 4–85 km).

The database is managed by an independent electronic data capture provider (Lambda-plus, Gembloux, Belgium), which also manages the internal data quality. An external commission audited the data validity of 5% of the patient files, and the database was registered on clinicaltrials.gov (NCT00727623). The database was approved by the Belgian Data Protection Agency. Informed consent was obtained from all patients or their legal representatives.

Baseline risk assessment and treatment strategy

A number of baseline characteristics for each patient were registered which allowed us to risk stratify the patients according to a previously validated TIMI risk score[18]: age, gender, history of coronary artery disease or peripheral artery disease, active smoking, location of the infarction, body weight, total ischaemic time (time from onset of symptoms until time of treatment), haemodynamic status before initiation of reperfusion therapy (Killip class), and history of hypertension, diabetes mellitus, chronic kidney disease (Glomerular filtration rate < 60 mL/min/1.73 m^2), or hyperlipidaemia. Cardiac arrest before initiation of reperfusion therapy was also registered, as this factor is not incorporated into the TIMI risk score.

All treatment decisions were made at the discretion of the treating physicians.

Quality indicators

We selected a set of QIs based on international guidelines for the management of STEMI and the ACCA Task Force on Quality Indicators.[13]

(1) Types of reperfusion strategy: thrombolysis (TL), pPCI, or no reperfusion.
(2) Time delays between diagnosis and treatment, subdivided into diagnosis-to-balloon time (time between first ECG with STEMI diagnosis and balloon inflation, recommended time delay < 90 min) and door-to-balloon time (time between arrival at the PCI centre and balloon inflation, recommended time delay < 60 min).
(3) In-hospital medication: proportion of patients receiving P2Y12 inhibitors and statins.

These indicators describe five process QIs, whereas the ESC-ACCA QIs for STEMI include eight main and five secondary process QIs. Four of them were redundant in this study, as the participating hospitals needed to be part of an established STEMI network and needed to register the data (including the data for risk stratification). Four QIs could not be calculated because information about cardiac function or patient satisfaction was not captured by the STEMI database. For each QI a score at network level was given from 0 to 2 based on data from the literature and based upon the median and the quartiles of the indicators observed in this study (see *Tables 1 and 3*).[19]

In addition, a composite quality score was calculated from the summation of the individual scores, with a maximum score of 10. A higher score reflects better adherence to the quality recommendations.

Missing data about baseline characteristics, reperfusion therapy, and mortality were present in <5% of patients file (see *Table 2*). In 9% of

patient's data about statin/P2Y12 were lacking, whereas in 25% of the patients no data about timelines were available (see *Table 3*).

Clinical outcome

The main clinical endpoint was in-hospital death from any cause as late as 30 days after admission. Vital status was assessed at the final hospital to which the patient was admitted before discharge.

Statistical analysis

Continuous variables are presented as the mean ± SD or as median values with interquartile range (IQR). Comparisons between cluster of networks were performed with ANOVA (cluster with high vs. intermediate vs. low QI performance). Per network, summary statistics were calculated for each of the parameters of interest i.e. median for continuous variables and percentages for categorical variables. With these summary statistics, an analysis on network level is performed. Independent determinants of in-hospital death were determined by means of simple and multiple weighted linear regression analysis. The following factors were included in this analysis: percentage of cardiac arrest, median TIMI risk score, and global QI score of each network. In order not to overfit our data a stepwise linear weighted regression analysis was manually performed to identify the relationship between in-hospital mortality and the individual components of the QI scores. This selection procedure was based on significance of the components, variance inflation factors, and clinical importance. As 32 networks are included in the analyses, we aimed to select a final model with at most 3 or 4 independent variables. Size of the network was included as weights in all regression models.

Added variable plots (also known as partial regression plots) were generated to show the relation between the composite quality score and mortality after correcting for case mix (cf TIMI risk score and cardiac arrest rate).

A sensitivity analysis was carried out using multiple imputation with chained equations. Imputation at patient level was based on all baseline characteristics and all QIs. These imputed data were summarized per network in the same way as in the original database. Ten imputations were performed and results of the models on the imputed datasets were pooled.

For all analyses, a *P*-value of <0.05 was considered statistically significant. All statistical analyses were performed using R Foundation statistical Software version 3.4.4 (R Foundation for Statistical Computing, Vienna, Austria).

Table 1 Quality indicator scores

	Score = 0	Score = 1	Score = 2
Reperfusion therapy: % PCI	<90%	90–95%	>95%
% Diagnosis-to-balloon time <90 min	<60%	60–80%	>80%
% Door-to-balloon time <60 min	<60%	60–80%	>80%
% P2Y12 inhibitors at discharge	<90%	90–95%	>95%
% Statins at discharge	<90%	90–95%	>95%

PCI, percutaneous coronary intervention.

Results

Baseline characteristics

Table 2 presents the baseline characteristics at the patient level and at the network level. Thirty-two percent of STEMI patients were transferred from a non-PCI hospital to a PCI-capable hospital. The cardiac

Table 2 Baseline characteristics

	Missing data (%)	Patient level (*N* = 7774) Global median (Q1–Q3) or proportion (%)	Network level (*N* = 32) Range of medians/proportions per network
Age	<1%	62 (53–73)	57–67
Male gender, %	<1%	76%	68–83
AHT, %	<1%	47%	36–64
DM, %	<1%	17%	11–25
CAD, %	<1%	15%	1–23
PAD, %	<1%	7%	2–18
Active smoker, %	4%	42%	30–58
CKD, %	4%	8%	0–21
Anterior MI, %	<1%	43%	19–54
Weight <67 kg	<1%	18%	7–28
Time between onset of pain and treatment <240 min, %	2%	55%	37–69
Killip class >1, %	1%	80%	62–94
Cardiac arrest, %	1%	11%	3–19
TIMI risk score	2%	4 (2–6)	2.9–4.7
Transfer to PCI hospital, %	2%	32%	0–63

Values are presented as the median ± interquartile range (IQR) or percentages at the individual level, and as range of medians, or range of percentages, at the network level.
AHT, arterial hypertension; CAD, coronary artery disease; CKD, chronic kidney disease; DM, diabetes mellitus; PAD, peripheral artery disease; SBP, systolic blood pressure; TIMI risk score, Thrombolysis in Myocardial Infarction risk score.

Table 3 Adherence to quality indicators

	Patient level (*N* = 7774)		Network level (*N* = 32)		
	Missing data (%)	Proportion (%)	Median proportion	Q1–Q3	Min–max
PCI, %	1%	95%	97%	96–99	44–100
Door-to-balloon time<60 min, %	25%	68%	67%	50–78	31–97
Diagnosis-to-balloon time <90 min, %	23%	63%	68%	53–71	27–95
P2Y12 at discharge, %	9%	97%	97%	96–98	88–100
Statins at discharge, %	9%	94%	96%	93–98	72–100

PCI, percutaneous coronary intervention.

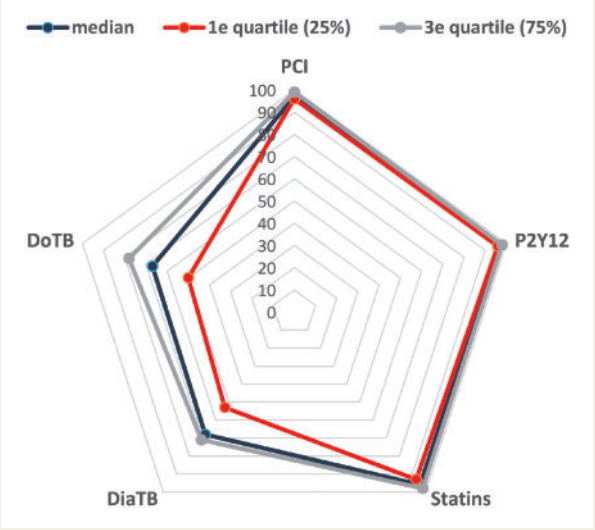

Figure 1 The radial flowchart showing the adherence rate of five Qis. DoTB, door-to-balloon time; DiaTB, diagnosis-to-balloon time; PCI, percutaneous coronary intervention.

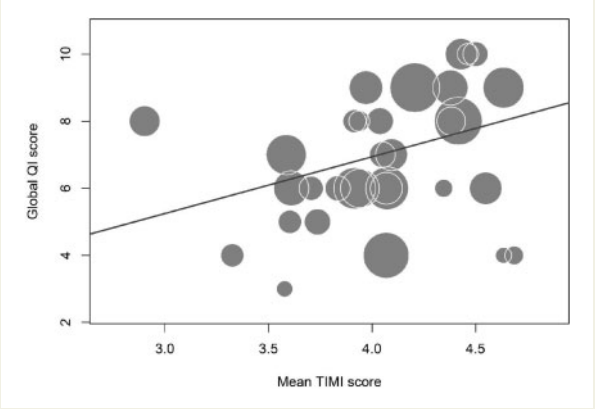

Figure 2 Graph showing the correlation between TIMI score and composite quality indicator score ($r^2 = 0.36$, $P = 0.041$). Each sphere represents a network, and the size of the spheres reflects the number of enrolled patients.

arrest rate was 11%, and haemodynamic instability was observed in ~20% of the cases.

Median TIMI risk score was 4.0 (Q1–Q3: 2.0–6.0) over all patients. Per network, the median varied from 2.9 to 4.7.

Quality assessment

Figure 1 and *Table 3* describe the QIs at the network level.

Primary PCI was the predominant reperfusion therapy (median 97%).

The median diagnosis-to-balloon time was 93 min (IQR 79–106 min), whereas the median door-to-balloon time was 58 min (IQR 45–74 min). Across the different networks, the recommendations for DiaTB <90 min and DoTB <60 min were achieved in 68% (IQR 53–71) and 67% (IQR 50–78), respectively. The use of P2Y12 inhibitors and statins was high, 97% (IQR 96–98) and 96% (IQR 93–98), respectively. The radial flowchart shows that the main gaps in quality adherence were related to time delays.

The average composite QI score was 6.8 ± 1.9 with a median of 6.5. A total of 16% of the networks had a QI score <5, and 22% of the networks had a QI score >8. There was a positive correlation between quality adherence and TIMI score (see *Figure 2*).

Quality indicators and their relationship with in-hospital mortality

The median in-hospital mortality of the total study population was 6.2% (IQR 4.1–7.9) and varied between 0% and 14% among the PCI networks. *Figure 3A* shows the relationship between the composite QI score and the in-hospital mortality for the different networks. No significant relationship was observed.

However, when correcting for the baseline risk profile, the relationship between lower mortality and higher QI score became evident (partial correlation coefficient: -0.45, $P = 0.013$) (see *Figure 3B*).

Table 4 shows the regression analysis between in-hospital mortality and the composite QI score and baseline risk profile. Quality adherence and the baseline risk profile (particularly presence of cardiac arrest) were independent predictors of in-hospital mortality. Stepwise regression analysis revealed that among the individual QIs, the diagnosis-to-balloon time was the most important independent predictor of in-hospital mortality (*Table 5*). Sensitivity analysis for missing data led to the same conclusions (Supplementary material online). A comparison of networks with different levels of adherence

to the diagnosis-to-balloon time recommendations is shown in *Table 6*. There is a trend towards better quality adherence in hospitals receiving patients with a higher risk profile ($P = 0.1$ for TIMI risk score and $P = 0.07$ for cardiac arrest)

Discussion

The present report describes the relation between adherence to STEMI QIs and in-hospital mortality at the level of STEMI networks. Our study shows a strong relationship between compliance with QIs and in-hospital mortality adjusted for the baseline risk profile. This relationship was mainly driven by a gap in the domain of timely reperfusion.

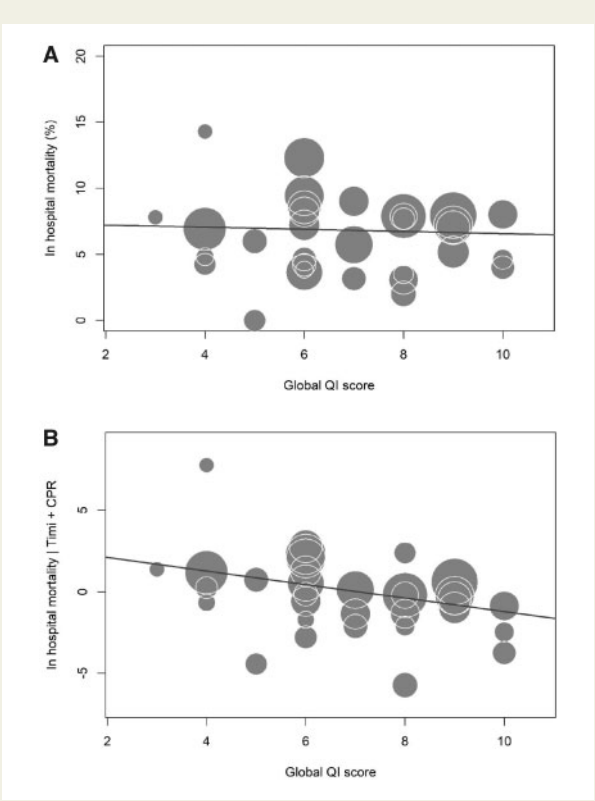

Figure 3 Partial regression plots showing the relationship between composite quality indicator and mortality before correcting for TIMI risk score and cardiac arrest rate (*A*, $P = 0.76$) and after correcting for TIMI risk score and cardiac arrest rate (*B*, $P = 0.021$). Each sphere represents a network, and the size of the spheres reflects the number of enrolled patients.

The present findings are in line with recent national registries in France, the UK and Portugal that have also documented an adjusted short- and long-term mortality risk linked to suboptimal adherence to QIs.[14–16] In all these registries, quality of care was studied at the patient or hospital level but not at the network level. Evaluation at the network level has the advantage of including information about the transfer of patients from non-PCI hospitals to PCI-capable hospitals and of reducing patient selection bias. Hospitals with advanced medical care will attract more high-risk patients, such as cardiogenic shock or refractory cardiac arrest and due to the strong impact of baseline risk profile on outcome, will have higher in-hospital mortality than hospitals without high level intensive cardiac care. For this reason, performance analysis of STEMI management should be done preferable at the network level.

Among the established QIs, we identified diagnosis-to-balloon time <90 min as the most important QI for in-hospital mortality. This confirms what has been shown previously in large-scale studies at the patient level.[17,20] The other individual QIs were not independently related to outcome, which is in contrast to previous quality-of-care registries. The high adherence (>90%) to the reperfusion therapy and the post-discharge medical treatment recommendations in our registry most likely masked the established relationship between those QIs and mortality. Among the participating networks, gaps in compliance were mainly observed in the domain of timely reperfusion. The median diagnosis-to-balloon time was 93 min, and the target diagnosis-to-balloon time was achieved in only 68% of the cases. In comparison, the median diagnosis-to-balloon time was 105 min in the French registry and 185 min in the UK registry. In the present study, diagnosis-to-balloon time was a better predictor of outcome than door-to-balloon time. This underscores the importance of covering the whole STEMI pathway from diagnosis (either pre-hospital or in a non-PCI hospital) to treatment in a PCI hospital. In the present study, neither the distances between the PCI hospital and the referring hospitals nor the proportion of transferred patients seemed to have significantly affected the diagnosis-to-balloon time. The short distance (on average 20 km) and the high number of PCI hospitals in Belgium, which limit the need to transfer, are possible explanations for this observation. Interestingly, hospital networks taking care of more high-risk STEMI patients tended to have a better quality score. This suggests that a more advanced level of care also begets better quality of care as was observed also in other studies.[21,22]

The present study may challenge the need to continuously monitor all established QIs. Based upon the present findings, future

Table 4 Predictors of in-hospital mortality

	Simple linear regression		Multiple linear regression	
	Estimate (SE)	***P*-value**	**Estimate (SE)**	***P*-value**
Composite QI score	-0.083 (0.27)	0.76	-0.50 (0.20)	0.021
TIMI risk score	2.20 (1.18)	0.073	1.25 (0.97)	0.21
% Cardiac arrest	0.45 (0.09)	<0.001	0.47 (0.09)	<0.001

Table 5 Predictors of in-hospital mortality

	Simple linear regression		Stepwise multiple linear regression	
	Estimate (SE)	*P*-value	Estimate (SE)	*P*-value
% PCI	-0.021 (0.047)	0.67		
%door-to-balloon time<60 min	-0.003 (0.027)	0.90		
%diagnosis-to-balloon time<90 min	-0.009 (0.031)	0.78	-0.061 (0.025)	0.019
% P2Y12 at discharge	0.20 (0.20)	0.33		
% Statins at discharge	-0.039 (0.069)	0.58		
TIMI risk score	2.20 (1.18)	0.073	1.71 (1.03)	0.11
% Cardiac arrest	0.45 (0.09)	<0.001	0.45 (0.09)	<0.001

PCI, percutaneous coronary intervention; QI, quality indicator; TIMI risk score, Thrombolysis in Myocardial Infarction risk score.

Table 6 Network characteristics according to adherence to DiaTB QI

	Networks with good DiaTB <60% (*n* = 15)	Networks with good DiaTB 60–80% (*n* = 11)	Networks with good DiaTB > 80% (*n* = 6)	*P*-value
Network size (no. of hospitals)	3.3 ± 1.2	2.7 ± 1.3	3.0 ± 1.3	0.6
Distance, km	22 ± 22	16 ± 8.5	24 ± 28	0.6
% transfer	24 ± 20	31 ± 17	19 ± 22	0.50
TIMI score	3.9 ± 0.4	4.0 ± 0.5	4.3 ± 0.3	0.13
% CA	9 ± 4	10 ± 3	13 ± 4	0.072
Mortality	6.5 ± 3.6	5.9 ± 2.4	6.3 ± 2.0	0.91

Values are presented as the mean ± SD or as *n* (%).
CA, cardiac arrest; Good DiagTB, diagnosis-to-balloon time < 90 min; QI, quality indicator; TIMI risk score, Thrombolysis in Myocardial Infarction risk score.

quality-of-care evaluations could be restricted to continuous evaluation of QIs not achieving >90% adherence with intermittent snapshot survey of the other QI's to ensure high quality of care in all domains. This would allow us to more extensively measure and explore the existing gaps in adherence (e.g. timely reperfusion). We have previously shown that more systematic use of the Emergency Medical Services system for patients with chest pain suspected for acute myocardial infarction will improve the diagnosis-to-balloon time, mainly because of a direct transfer to the PCI hospital, thus bypassing non-PCI centres.[23] Other measures can be taken to shorten the DiaBT, such as early notification of the catheterization laboratory team and direct transfer to the Cath lab, bypassing the emergency room.[24,25]

The results of this study should be considered in the context of the following limitations. As only patients with (near) complete data were extracted from the STEMI database, selection bias towards centres with the best data quality could have generated more favourable data. Previous studies have shown that underreporting is associated with less adherence to recommended reperfusion therapy.[26] As the score system of QI was based upon the median and distribution of QI's in the studied population, those absolute values cannot be automatically applied to other countries.

In conclusion, evaluation of the quality of care of STEMI patients at the network level is of added value as it covers the whole chain of care from pre-hospital care to in-hospital treatment across different hospitals belonging to the network. In addition, our data illustrated that high levels of performance according to the QIs are likely to reduce unwarranted variation and premature death from STEMI.

Data availability

Access to data can be obtained on request to the corresponding author.

Supplementary material

Supplementary material is available at *European Heart Journal – Quality of Care and Clinical Outcomes* online.

Conflict of interest: non declared.

Acknowledgements

We thank all the investigators for recording the data from their STEMI patients in the database.

Funding

The National STEMI Database is financially supported by the Belgian government.

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