THE OPERATIONAL RESEARCH STUDY FOR THE SINGAPORE MYOCARDIAL INFARCTION REGISTER

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SYNOPSIS

The Singapore Myocardial Infarction Register(SMIR) was set up in January 1987 to capture all events of acute myocardial infarctions(AMI) in the country. The operational research study for the SMIR was carried out in March 1987 and three methods of notification of AMIs were evaluated. Specifications of the WHO MONICA project were applied to the SMIR. The study showed that the investigation of Creatine Phosphokinase (CPK) tests whose levels were above normal, was the best single source of notification of AMI cases to the Register.
The study estimated the incidence of AMI among Singapore as 2.5 per 1000 population aged 40-64 years.

Keywords

SMIR — Singapore Myocardial Register
WHO MONICA Project — World Health Organisation Monitoring of Trends and Determinants in Cardiovascular Diseases
Creatine Phosphokinasa test notification. Incidence of AMI

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INTRODUCTION

Singapore is an island-republic covering some 620 square kilometres and located at the tip of the Malaysian Peninsular in Southeast Asia. It is a completely urbanised society with a population of 2.6 million (1)people, comprising 76% Chinese, 15% Malays, 7% Indians and 2% of other racial groups. The population is relatively young with 23% aged below 15 years of age, 69% between 15 to 59 years and 8% aged 60 years and above.

The state of health in Singapore is good. The Infant Mortality Rate in 1987 was 7.4% per thousand live births. Expectation of life at birth for the same year was 71.4 years for males and 76.3 years for females.

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The last two decades have seen rapid socio-economic develpoments within the country, with the GNP per capita currently US$7,850 (2). Associated with the socio-economic growth, there has been a change in the mortality profile of the country, which today is dominated by the degenerative conditions such as heart diseases, cancers and strokes. In 1987, these three diseases alone accounted for 56% of the total 13,200 deaths in the year (3). As a single disease entity, ischaemic heart diseases is the leading cause of death and is respondsible for some 2,500 deaths each year.

It was the overriding concern for the future state of health in the country that led to the formulation of a National Cardiovascular Programme in 1986, and it was to evaluate this Programme that the Singapore Myocardial Infarction Registry (SMIR) was set up in January 1987.

The SMIR was designed to capture data on all events of Myocardial Infarction occuring in the country. The Registry is the collaborative effort of the Ministry of Health and the Singapore National Heart Association. The SMIR is operated by a reseach team comprising two nurses, a computer programmer and a data- entry clerk. Professional support to the Registry is provided by the Department of Cardiology, Singapore General Hospital and the Research and Evaluation Department of the Ministry of Health

In January 1987, Prof Huge Tunstall-Pedoe, Professor of Cardiovascular Epidemiology, University of Dundee, Scotland, spent three weeks in Singapore as a WHO short-term consultant to assist in the setting up of the SMIR. Under Prof Tunstall-Pedoe's guidance, a month-long operational research study was drawn up for the month of March 1987. The main objective of the study was to determine the most effective method for capturing information on all events of Myocardial Infarction in Singapore. The study would also indicate the caseload for the Singapore Register and help finalise operational procedures to run it. It would, in addition, serve as a reference frame for the validation of date obtained from the Register, when it became fully operational.

Although Singapore is not an officially recognised

MONICA centre, the specifications of the WHO MONICA project were applied, whenever possible, to data capture for the Singapore Register, so that results obtained would have international comparability. The notable difference during the one-month operational research study, was that the notification of fatal cases was confined to deaths diagnosed as Acute Myocardial Infarction deaths (ICD 9th Revision) and did not include possible coronary deaths (ICD 410- 414), as is the practice in thw WHO MONICA centres. When the Singapore Register is fully operational, however, it is intended that notification of deaths to the Register would be extended to include both Acute Myocardial Infarction deaths and possible coronary deaths (ICD 910-414).

This paper presents the results of the evaluation of the operational research study for the Singapore Myocardial Infarction Register.

METHODOLOGY

Four sources for notification of Acute Myocardial Infarction for the Register were undertaken and evaluated during the study period. These will be discussed under notifications for Non-Fatal cases which refer to cases which were alive when first diagnosed by the doctor, and Fatal cases which refer to cases which were dead when the diagnosis and notification were made.

a) Notification of Non-Fatal cases were from the following sources:
   (i) notification through all Creatine Phosphokinase (CPK) tests performed in March 1987;
   (ii) voluntary notification by all doctors practising in Singapore of cases of Acute Myocardial Infarction (AMI) they diagnosed in March 1987;
   (iii) all discharges (diagnosed as AMI) from Government and private hospitals of patients admitted during March 1987.

b) Notification of Fatal cases came from:
   (iv) Death Statistics of deaths attributed to AMI in March 1987.

As almost all Myocardial Infarction diagnosed in Singapore, except for a few occurring among the very old,are managed in hospital, the operational research study was confined to acute hospitals. For methodology procedures (i) and (iii) listed above, two major acute Government general hospitals, the Singapore General Hospital (SGH) and Alexandre Hospital (AH) and a large private hospital, Mount Elizabeth Hospital (MEH) were involved. The target population for the study consisted of Singapore Citizens and Permanent Residents under the age of 65 years who were diagnosed as new cases of A ute Myocardial Infarction in the month of March 1987. (New refers to a case which developed the specified condition during the study period.)

(I) Notification Through CPK Tests

For all hospitals run by the Ministry of Health, the Ministry's Department of Biochemistry has a central record of all CPK enzyme tests performed each day. By special arrangement with the Ministry's Biochemistry Laboratory and Mount Elizabeth Hospital's Laboratory, daily results of all CPK tests performed during the month of March 1987, on patients of the 3 hospitals selected were forwarded to the SMIR. The CPK results were classified (4a) as follows;

(a) abnormal (Enzyme category 1)— where at least one CPK reading was more than twice the upper limit of normal;

(b) equivocal (Enzyme category 2) — where CPK results were raised but were less than twice the upper limit of normal;

(c) non-specific (Enzyme category 3) — where there was an elevation of the CPK levels, but which on investigation was shown to be attributable to a cause other than AMI and

(d) normal (Enzyme category 4) — within normal limits.

(ii) Voluntary Notification By Doctors.

For the method of notification, a high level of press and TV coverage was given to the operational research study during the two months preceeding the study. In addition, individual letters were sent to all doctors on the Singapore Medical Council Register and the administrators of the 3 large acute hospitals involved in the study, informing them of the SMIR, its objectives and the month-long study to be carried out. The cooperation of all doctors was sought to complete the form that had been drawn up for the study, for each new case of AMI they saw during the month of March 1987. The format for returns is presented in Appendix 1.

(iii) Inpatient Discharges

Inpatient discharges from the computerised Patient Master Information (PMI) System for Government hospitals and private hospitals were scanned to select patients admitted in March 1987. From these, cases for which a diagnosis of AMI (ICD Code 410) was made, were extracted for study.

To increase the comprehensiveness of coverage, all cases assigned a discharge diagnosis code of between ICD Code No. 410 to 414 were screened and investigated.

(iv) Official Death Statistics

For the final source of notification, arrangements were made with the Registrar of Births and Deaths in Singapore, to provide the SMIR with data on all deaths due to AMI (ICD 9th Revision) which occurred during the month of March 1987. As there is a statutory allowance of 14 days provided for the registration of deaths in Singapore, records from the Registrar were requested only 2 months after the study period had ended.

To increase comprehensiveness of coverage, arrangements were also made with the mortuary at SGH in which the postmortems of all Corner's cases are carried out, to have the SMIR notified of all Corner's cases diagnosed as AMI. This was ensure that Corner's cases, which were assigned a diagnosis of AMI but whose diagnosis had still not been entered onto the death certificate at the time of analysis due to some unforseen delay,would not be excluded from the study.

Statistics on fatal cases of AMI were to supplement the number of non-fatal AMI cases obtained by the three methods listed earlier, in order to provide a complete enumeration of AMI cases which occurred in the country during the period of the month-long study.

Confirmation of Diagnosis

All patients notified by any of the 4 methods

described earlier, had relevant clinical and enzyme data extracted by the SMIR nurses from the patient's medical records. The prescribed registration form designed for the study (see Appendix 2) was completed for each case by the nurses. In addition, ECGs were photocopied from the medical records and coded according to the Minnesota coding.

Based on the definitions laid down by the WHO MONICA project, using the combination of information derived from clinical, ECG and enzyme sources, all cases were then classified into the following four Dianostic Categories (Diag. Cat) of AMI, in accordance with the WHO MONICA study (4b);

(a) **Category 1** — definite Acute Myocardial Infarction;

(b) **Category 2** — possible Acute Myocardial Infarction;

(c) **Category 3** — ischaemic cardiac arrest with successful resuscitation, not fulilling criteria for definite or possible Acute Myocardial Infarction; and

(d) **Category 4** — either Acute Myocardial Infarction nor a coronary death.

QUALITY CONTROL

To ensure that all eligible cases had been correctly identified, documented and the diagnosis subsequently accurately assigned by the SMIR nurses, a fixed panal of 3 Cardiologists from the Cardiology Department, SGH, checked on the diagnostic categorisation and ECG coding of all cases screened during the study period. This was done to eliminate any inter-investigator variability from the study. The 3 Cardiologists had worked with the Prof Tunstall-Pedoe during his consultancy assignment.

DATA PROCESSING AND ANALYSIS

Data collected on the registration forms were stored in a database on a micro-computer. A specially developed programme utilising the MONICA project's ECG algorithm (4c) was used to derive the ECG classification for diagnostic categorisation.

RESULTS

(i) Case Detection Through Cardiac Enzyme Notification

A total of 448 CPK tests were carried out in March 1987, on Singapore residents below the age 65 years, in the 3 hospitals covered by the study (Table 1). Of all 488 cases, 327 upon screening, were found to have their CPK levels attributable to conditions other than that of the heart and were therefore subsequently disregarded. The remaining 121 cases were classified into Diagnostic Categories (Diag. Cat.) 1,2,3, or 4.

Of the 121 cases, 39 belonged to Diag. Cat. 1 or were definite AMI. The conclusion drawn therefore was that if all CPK tests that are performed are used as a screening procedure to detect definite AMI cases, the method has a pick-up rate of 8.7%. For an operational procedure, this is a very low and inefficient output.

The study next went on to examine whether, if selective criteria were imposed on the CPK results, the yield in the pick-up rate of AMI by the CPK notification method could be improved.

The table below illustrates the change in the proportion of Diag. Cat. 1 (definite AMI) cases detected by the CPK method, by including the various enzyme category (respresented by column 7). Results show that the various enzyme categories ranked in rising order have decreasing sensitivity to predict Diagnostic Cat. I cases(represented by column 8).
The results were as follows:-

(a) Enzyme Category 1 incorporates 89% of all Diag. Cat. 1 cases detected by the CPK method. This enzyme category on its own, thus has a positive predictive value of 95% for definite AMI cases detected by the CPK method.

(b) By including Enzyme category 2 cases into the CPK notification systems, the yield of capturing Diag. Cat. 1 from the CPK method, improved to 92%. This increased sensitivity was achieved however at the expense of a decrease in the positive predictive value to 69%.

(c) The inclusion of Enzyme Category 3 improved the sensitivity of detecting Diag. Cat. 1 cases to 95%.

TABLE 1
CASE DETECTION THROUGH CARDIAC ENZYME NOTIFICATION

Hospital	No. of CPK Tests Reviewed by Nurses	Cases Classified as Diag. Cat. 1, 2, 3 or 4	Cases Classified as Diag Cat. 1
SGH	343	85	28
AH	100	32	9
MEH	5	4	2
TOTAL	448	121	39

TABLE 2
ENZYME CATEGORY BY POSITIVE VALUE TO DETECT DIAG. CAT. I

Enzyme Category	Total	Cumulative Total	Diag. Cat. 1				Positive Predictive Value
			No.	%	Cumulative No.	Cumulative %	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	37	37	35	89	35	89	95
2	15	52	1	3	36	92	69
3	4	56	1	3	37	95	66
4	65	121	2	5	39	100	32

This was at the expense however, of decreasing the positive predictive value to 66% .

(d) To improve the sensitivity of detecting Diag. Cat. 1 cases to 100% by including Enzyme category 4, the positive predictive value fell to a low of 32%.

This study has shown therefore that, as a notification procedure for AMI cases to the Register, by imposing criteria on the CPK results in order to select cases for futher investigation by the SMIR staff, the positive predictive value of the CPK method improves greatly. If CPK results which are above normal are selected as cases to be investigated by the SMIR nurses, 95% of definite AMI cases detected by the CPK method will be captured into the Register. This level of sensitivity of the method is however achieved at the expense of having a positive predictive value of the method of 66.%.

(ii) Case Detection Through Voluntary Notification by Doctors.

A total of 88 notifications of Myocardial Infarction were receive by the Registry through voluntary notifications from doctors. Of these, 82 cases from doctors in the public sector and 6 from doctors in the private sector.

Forty-three of the notifications were received from doctors in the 3 acute hospitals included in the CPK notification study method (i.e. SGH, AH and MEH).

On investigation, it was found that half (23) of the 43 cases notified from the 3 acute hospitals had also been notified by the CPK method. These 23 cases were of the following Diagnostic Category distribution: (Table 3.2)

Of the remaining 20 cases notified from the 3 hospitals but not captured by the CPK method, one case was from the A&E Dept of SGH. This, on investigation, was found to belong to Diag. Cat. 1. The other 2 cases from MEH and 1 case from AH belonged to Diag. Cat. 4.

The remaining 16 notifications by doctors were from doctors in the Dept of Pathology SGH and were of coronary deaths. These cases would be enumerated and discussed under the mortality statistics in this Report.

Thus of the 27 non-fatal notifications received from doctors of the 3 acute hospitals, 16 belonged to Diag. Cat. 1 and 11 to Diag. Cat. 4. The voluntary notification

TABLE 3.1
VOLUNTARY NOTIFICATIONS BY DOCTORS

Hospital	Number of Notifications
SGH	32
AH	6
MEH	5
Sub-Total	43
Other Hospitals/ Clinics	45
GRAND TOTAL	88

TABLE 3.2
VOLUNTARY NOTIFICATIONS ALSO NOTIFIED BY CPK METHOD, BY DIAGNOSTIC CATEGORY

Hospital	Diagnostic Category				Total
	1	2	3	4	
SGH	9	–	–	6	15
AH	4	–	–	1	5
MEH	2	–	–	1	3
Total	15	–	–	8	23

method by doctors was therefore much less comprehensive than the CPK notification method (16 cases vs 39 cases). The voluntary notification method however, picked up 1 case of definite AMI not detected by the CPK method.

(iii) Case Detection Through The Inpatient Discharge Summary

For this method, to improve comprehensiveness, all cases admitted in March 1987, who on discharge were assigned a diagnosis code of ICD Code No. 410 to 414 were extracted from the computerised Patient Master Index (PMI) System of the 3 hospitals, and reviewed.

Altogether 283 discharges were extracted from the 3 hospital bearing ICD codes of between 410 to 414.(Table 4)

On investigation, it was found that 185 cases had been notified by the CPK method as well. Of these, 27 cases belonged to Diag. Cat. 1.(Table 5)

Of the 98 remaining cases detected through the discharge summary method alone, 2 on further investication, belonged to MONICA Diag. Cat. 1. These 2 cases had been assigned an ICD code of 410.(Table 7)

This shows that a total of 29 cases of definite AMI were detected through the Inpatient Discharge Summary method, 19 of whom had been correctly diagnosed by doctors as AMI (ICD Code 410) while the remaining 10 had, on clinical assessment, been assigned ICD Codes of between 413 (2 cases) and 414 (8 cases).

The discharge summary notification method was therefore also shown to be less comphrensive than the CPK notification method (29 cases vs 39 cases). The discharge summary method however, detected 2 cases not capture by the CPK method.

In summary, the evaluation of the effectiveness of the 3 method used for the notification of non-fatal AMI cases to the SMIR during the month-long operationa research study, showed that of the total of 42 AMI cases notified, 39 were notified by the CPK method, 29 by the Discharge Summary method and 16 through Voluntary Notifications by doctors.

TABLE 4
POSSIBLE AMI CASES DETECTED THROUGH DISCHARGE SUMMARY BY HOSPITAL AND DIAGNOSIS CODE

Diagnosis Code	Hospital			Total
	SGH	AH	MEH	
Total	204	48	32	283
410	26	15	4	45
412–414	178	33	27	238

Diagnosis Codes ICD 9th Revision
410 — AMI
411 — Other acute and subacute forms of ischaemic heart disease
412 — Old AMI
413 — Angine Pectoris
414 — Other forms of Ischaemic Heart Disease

TABLE 5
CASES NOTIFIED THROUGH BOTH CPK METHOD AND DISCHARGE SUMMARY, BY DIAGNOSTIC CATEGORY

Diagnostic Code	Diagnostic Category				Total
	1	2	3	4	
Total	27	40	9	109	185
410	17	8	–	14	39
411	–	–	–	–	–
412	–	1	–	4	5
413	2	13	3	21	39
414	8	18	6	70	102

TABLE 6
POSSIBLE ACUTE MYOCARDIAL CASES NOTIFIED BY DISCHARGE SUMMARY METHOD ALONE BY DIAGNOSTIC CATEGORY

Diagnostic Code	Diagnostic Category				Total
	1	2	3	4	
Total	2	1	–	95	98
410	2	1	–	3	6
411	–	–	–	–	–
412	–	–	–	3	3
413	–	–	–	9	9
414	–	–	–	80	80

TABLE 7
NOTIFICATION OF NON-FATAL DEFINITE AMI BY SOURCE OF NOTIFICATION

Method	Total Cases Detected	% of Total	Number of Cases Detected by Respective Method Alone
Total Cases	42	100	—
CPK	39	93	8
Discharge Summary	29	69	2
Voluntary Notification by Doctors	16	38	1

Notification of Fatal Cases

Returns of death records for the month of March 1987 from the Registrar of Death showed that 46 deaths had been assigned to AMI (ICD Codes 410: ICD 9th Revision).

As a second source of the death notifications, an additional 16 notifications were received from the mortuary of SGH. Of these, 7 deaths had been included among the Registrar's records. This left a total of 9 deaths which were notified from the mortuary alone.

The postmortem (PM) records of cases with postmortems and case records of all the other cases were investigated by the nurses and all information reviewed by the 3 Cardiologists.

In the enumeration of definite AMI detected during the study period, fatal cases which had also been captured by either the CPK method or from doctors' notifications of patients when they were alive were not included as these cases would have been already accounted for among the non-fatal cases. This was to ensure that there was no double-counting of patients when comput-

TABLE 8
DEATHS RECORDS BY SOURCE OF NOTIFICIATION AND DEATH RECORD CERTIFICATION

Death Records / Notification Source	Coroner's Cases with PM		Coroner's Cases without PM		Death certified by Doctors		Total	
	Notifications	Def. AMI	Notifications	Def. AMI	Notifications	Def. AMI	Notifications	Def. AMI
	From Registrar's Records							
Also Captured by CPK Method	0	0	2	2	3	1	5	3
Also Captured by Doctor's Notification	6	5	0	0	1	1	7	6
Notified Only from Death Records	2	2	5	5	27	23	34	30
Sub-Total	8	7	7	7	31	25	46	39
	From Mortuary SGH							
Notified by Doctor's from SGH Mortuary	8	6	1	1	0	0	9	7
Grand Total	16	13	8	8	31	25	55	46

ing the incidence of AMI for the country. On this basis, there were 30 cases of definite AMI derived only from the Registrar of Deaths' notifications (Table 8)

The 3 Coroner's Cases notified by doctors from the mortuary, reflected in Table 8, who had postmortems done and who were judged not to be definite AMI by the Cardiologists on the study panel, all had postmortem diagnoses of marked narrowing of the coronaries from artherosclerosis, without evidence of Myocardial Infarction on postmortem. These cases had been assigned an ICD code of 410 for their cause of death. However as the study was only to include only AMI deaths, these cases were not included in the computation.

In total therefore from mortality statistics, 37 cases of definite AMI were obtained for the SMIR from death records notifications.

INCIDENCE OF AMI IN SINGAPORE

By application of the case-load of AMI which occurred during the operational research study month, the annual incidence of AMI for Singapore can be estimated.

Findings from the pilot project showed that a total of 42 cases were detected from the 3 hospitals during the pilot project.

Thus the operational research study for the SMIR has shown that the incidence of non-fatal AMI cases in the country can be estimated to be 78 cases a month or 936 cases a year. If the incidence of fatal cases, which was computed to be 37 cases in the month, is incorporated, the total incidence of Acute Myocardial Infarction among Singaporeans and Permanent Residents under the age of 65 years, is 1,400 cases a year. This gives an annual ancidence rate of 2.5 cases per 1000 eligible population, defined as population aged between 40-64 years.

TABLE 9
DISTRIBUTION OF DEFINITE AMI CASES IN 3 ACUTE HOSPITALS INVOLVED IN PILOT STUDY

Notification Source	Hospital			Total
	SGH	AH	MEH	
CPK Notification	28	9	2	39
Notification by Doctors	1	–	–	1
Discharge Summary	–	1	1	2
Total	29	10	3	42

TABLE 10
ADMISSIONS AND INCIDENTS OF AMI BY HOSPITALS, 1986

Hospital	Government Hospitals *				Private Hospitals #					Total
	SGH	TTSH ☆	AH	TPH ☆	MEH	AMI ☆	MAH ☆	GH ☆	NUH ☆	
Admissions diagnosed as AMI	489	303	161	135	65	21	14	6	45	1239
Estimated AMI Case-load per Month	29	20	10	10	3	1	1	1	3	78

☆ AMI-related estimated for these hospitals based on incidence in 3 hospitals determined from study.

* **Government Hospitals**
SGH Singapore General Hospital
TTSH Tan Tock Seng Hospital
AH Alexandra Hospital
TPH Toa Payoh Hospital

\# **Private Hospitals**
MEH Mount Elizabeth Hospital
AMI American Hospital
MAH Mount Alvernia Hospital
GH Gleneagles Hospital
NUH National University Hospital

CONCLUSION

A month-long operational research study was carried out to determine the most effective operational procedure to obtain notification of all nem cases of Myocardial Infarction occuring among Singaporeans, for the newly established Singapore Myocardial Infarction Register. The study demonstrated that the investigation of all CPK tests whose levels were above nomal, was the best single source of notification for the Register, capturing 88% of all AMI cases which occured during the month. When supplemented by cases with discharge diagnosis of AMI, the coverage increased to 93%. This was therefore, the procedure selected to obtain notification of non-fatal definite AMI cases for the Singapore Register.

Fatal cases of AMI were most comprehensively and effectively notified through all deaths certified as due to AMI, from the Registrar of Deaths records, supplemented by notifications of AMI deaths from the mortuary of the Singapore General Hospital, where postmortems on all Coroner"s cases are carried out.

Based on the results from the month-long operational research study, the estimated incidence of Acute Myocardial Infarction among Singaporeans aged 65 years and below is 1400 cases a year giving an annual incidence rate of 2.5 per 1000 population aged 40-64 years.

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