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Original Article

Population access to reperfusion services for ST-segment elevation myocardial infarction in Kerala, India

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ABSTRACT

Background: Population access to timely reperfusion is a decisive factor in determining the success and acceptability of any regional system of ST-segment elevation myocardial infarction (STEMI) care. We sought to determine the proportion of population of the southern Indian state of Kerala having timely access to STEMI reperfusion.

Methods: We identified the STEMI reperfusion facilities available at all acute-care hospitals, in Kerala, by conducting a cross-sectional survey. We mapped the geographical catchment areas of these hospitals using historical travel speeds and appropriate Geospatial Information Systems (GIS) analyses. Subsequently, using block level population data, we estimated the proportion of the population residing within these geographies.

Results: We estimated that 23.33 million people, forming 69.84% of the state population, resided in the green zone (within half-hour travel distance of a percutaneous coronary intervention [PCI]-capable hospital), which covered 47.94% of the geographical area of the state. Outside this green zone, 21.87% of the state population resided within 1 hr travel distance of a thrombolysis-capable hospital. Finally, 8.28% of the state population resided in the red zone, where access to any reperfusion-capable hospital took >1 hr, which covered 22.15% of the geographical area of the state.

Conclusions: A majority of the population of Kerala had timely access to PCI-capable hospitals. GIS-based mapping of Indian states, in terms of access to STEMI reperfusion, may help devise protocols to achieve seamless transfer of patients to reperfusion-capable hospitals. Such regionalization of STEMI care would enhance organizational synergies to achieve better access to reperfusion, especially in remote areas.

1. Background

Ischemic heart disease is the leading cause of mortality in India,[1] and is the highest ranking cause of premature death in terms of number of years of life lost.[2] Acute coronary syndrome is a potentially life threatening manifestation of ischemic heart disease. ST-segment elevation myocardial infarction (STEMI) is the most common presentation of ACS in Indian patients.[3,4] India faces unique challenges when it comes to timely reperfusion of patients with STEMI.[4,5] These challenges include major heterogeneity in care, absence of systems of care for STEMI, limited access to emergency medical services (EMS), low STEMI reperfusion rates, poor penetration of health insurance, inadequate public funding for healthcare, and presence of cultural impediments to timely access of emergency services, in the face of a huge burden of acute coronary syndromes.[3–5]

Population access to timely reperfusion is a decisive factor in determining the success and acceptability of any regional system of STEMI care. The Cardiological Society of India has proposed a uniform policy for regionalization of STEMI care services.[6] Given the size and level of fragmentation of the Indian healthcare system, in order to develop an integrated system of STEMI care, we first

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need to understand the population access to emergency reperfusion services, at a provincial and national level. Access to timely reperfusion is predominantly determined by the distribution of a population in relation to healthcare facilities offering primary percutaneous coronary intervention (PCI) and/or fibrinolysis. Additional factors influencing the access to reperfusion includes travel times, efficiency of the EMS response system and finally cultural factors prompting patient to access EMS as opposed to traveling to a non-reperfusion-capable hospital or clinic.

Systems of care, regionalized according to the level of access to various modes of reperfusion, would help optimize the delivery of timely reperfusion for patients presenting with STEMI.[7]

2. Methods

This study covered the entire state of Kerala, a southern Indian state, having a population of 33.4 million. A detailed survey was undertaken to first create a master list of hospitals, both in the private and public sector, offering acute intensive care treatment facilities. From the list of medical institutions under the Kerala State Directorate of Health Services, we identified 18 general hospitals, 16 district hospitals and 79 taluk hospitals. In addition, there were 10 medical college affiliated teaching hospitals in the public sector. Representatives of these 123 public sector hospitals were administered a questionnaire to identify the STEMI reperfusion services available at these institutions. We contacted the intensive care unit in-charge, Physician or Cardiologist at these centers if a response was not elicited at the first contact attempt.

The list of private acute-care hospitals was created by collating a list obtained through local-expert consultations, a list of thrombolysis-capable hospitals obtained from 21 pharmaceutical companies distributing thrombolytic agents, a list of PCI-capable hospitals maintained with the Cardiological Society of India-Kerala Chapter, in addition to the list of 19 private medical college affiliated teaching hospitals. In total, we identified 309 acute-care private hospitals. Representatives of these hospitals were administered a questionnaire to identify the STEMI reperfusion services available.

We divided these 432 hospitals into 3 groups: those having catheterization laboratories offering primary-PCI services, those offering only thrombolysis and those that do not offer any reperfusion, for patients with STEMI. These hospitals were further segregated into government and private. Additionally, catheterization laboratories were sub-categorized into two groups according to whether or not they offer 24 × 7 primary PCI services.

The state of Kerala has 14 districts and 152 community development blocks. For this analysis the block and district boundaries were extracted from the Geographic Database of Global Administrative Areas (GADM version 1.0).[8] All reperfusion-capable hospitals were first located on Google earth software as kmz files and later converted to shapefiles using relevant tools in a geographic information system (GIS) software (ArcGIS version 9.0). These shapes were re-projected to the Universal Transverse Mercator coordinate system, utilizing WG S84 datum.

The next step in the analysis was to delineate the geographical area falling within 30 min travel time of each PCI-capable hospital. Travel times used in this analysis were derived using historical traffic data from Google navigation systems. For each catheterization lab, distance traversed in 30 min travel time was bookmarked along major roads, keeping the lab as the central point. These travel nodes were later interconnected by networking the shortest available public works department road or panchayat road. The polygon thus created was converted into a shape file and the relevant projection and datum was added. An attribute table was attached to each of these polygons. The overlapping areas of polygons subtended by nearby hospitals were merged. This polygon was overlaid onto the layer identifying the district and block boundaries. Thus, the geographical area covered by 30 min travel time for each catheterization lab could be identified. Similarly, we repeated the exercise separately for 1 h travel time for PCI-capable hospitals and thrombolysis-capable hospitals.

Block level population data was obtained from the 2011 Census of India.[9] The geographical area covered by 30 min travel distance from PCI capable hospitals and 1 h travel distance from thrombolysis capable hospitals were separately calculated. Using the block level population data, the proportional population covered by these facilities were identified.

All continuous variables were expressed as mean with interquartile ranges. Categorical variables were expressed as frequencies with percentages.

3. Results

As on July 2016, there were 432 acute care hospitals in Kerala. Among these, 258 hospitals were offering thrombolytic services for STEMI. Of these 258 hospitals, 104 had cardiac catheterization laboratories. One private-sector lab was non-functional. All the remaining 103 catheterization lab equipped hospitals were capable of doing primary PCI. There were 10 PCI-capable hospitals in the public sector and 93 PCI-capable hospitals in the private sector (Fig. 1).

The population of Kerala increased from 29.1 million in 1991 to 33.34 million in 2011.[10] The decadal population growth rate of the state declined from 9.43% (1991–2001) to 4.86% (2001–2011).[10] Meanwhile, as shown in Fig. 2, there was an exponential growth in the number of PCI capable hospitals in the state. The number of PCI-capable hospitals increased more than fivefold, from 18 to 103, over the last decade (2006–2016). In the year 2016, the state had 3.08 PCI-capable hospitals per million population. As shown in Table 1, there were regional disparities in the distribution of PCI-capable hospitals across various districts of Kerala (inter-quartile range 1.80–4.05 PCI-capable hospitals per million population). Ernakulam district had the highest density of PCI-capable hospitals in the state; whereas the northern district of Kasaragod did not have a catheterization laboratory. Of the 103 PCI-capable hospitals, 30.1% had only one interventionist capable of performing primary PCI. The remaining 69.9% of PCI-capable hospitals offered 24 × 7 primary PCI services for STEMI.

As shown in Table 2, five of the 14 districts had more than 80% of the population residing within half-an-hour travel distance of a

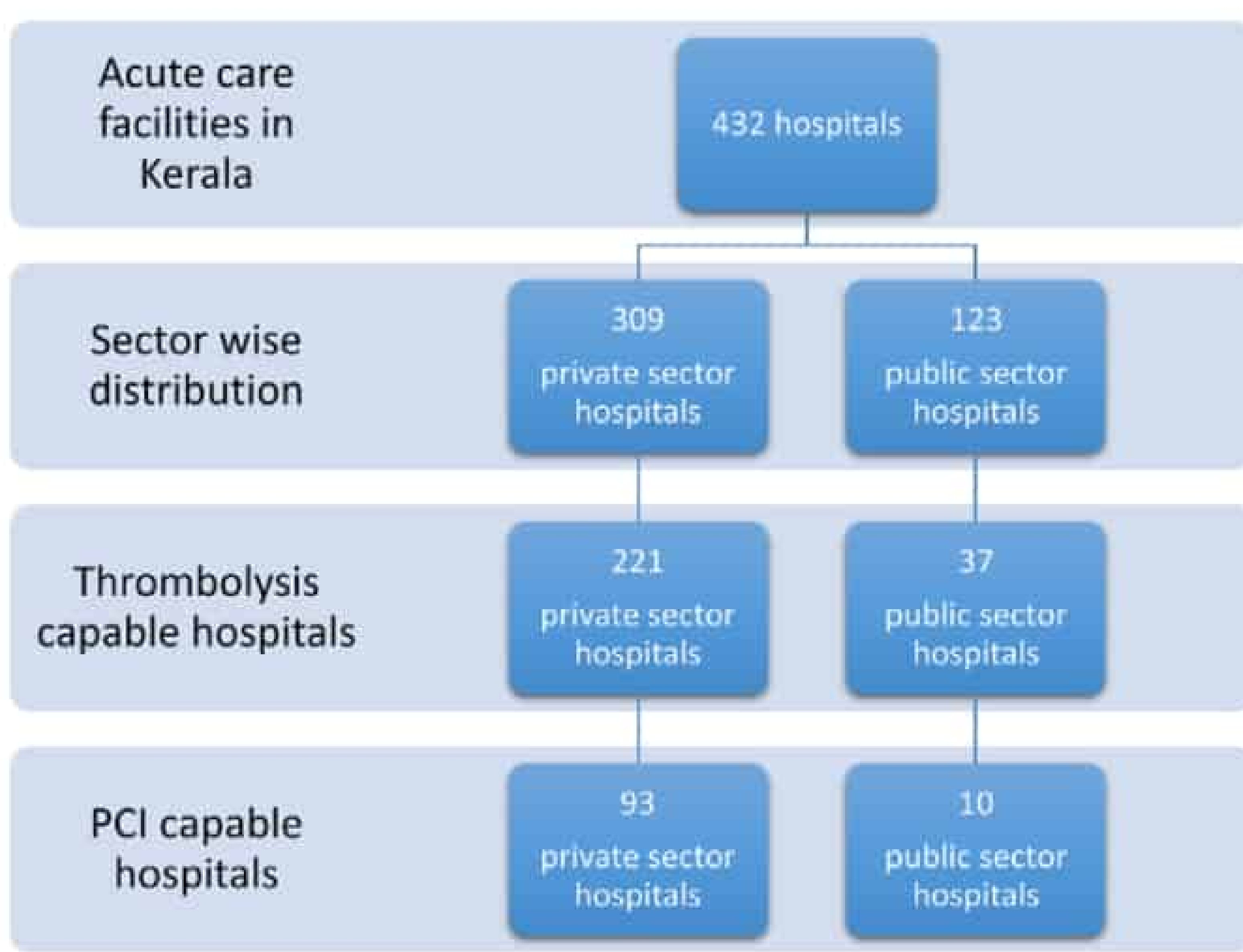

Fig. 1. Reperfusion facilities available at acute-care hospitals across Kerala.

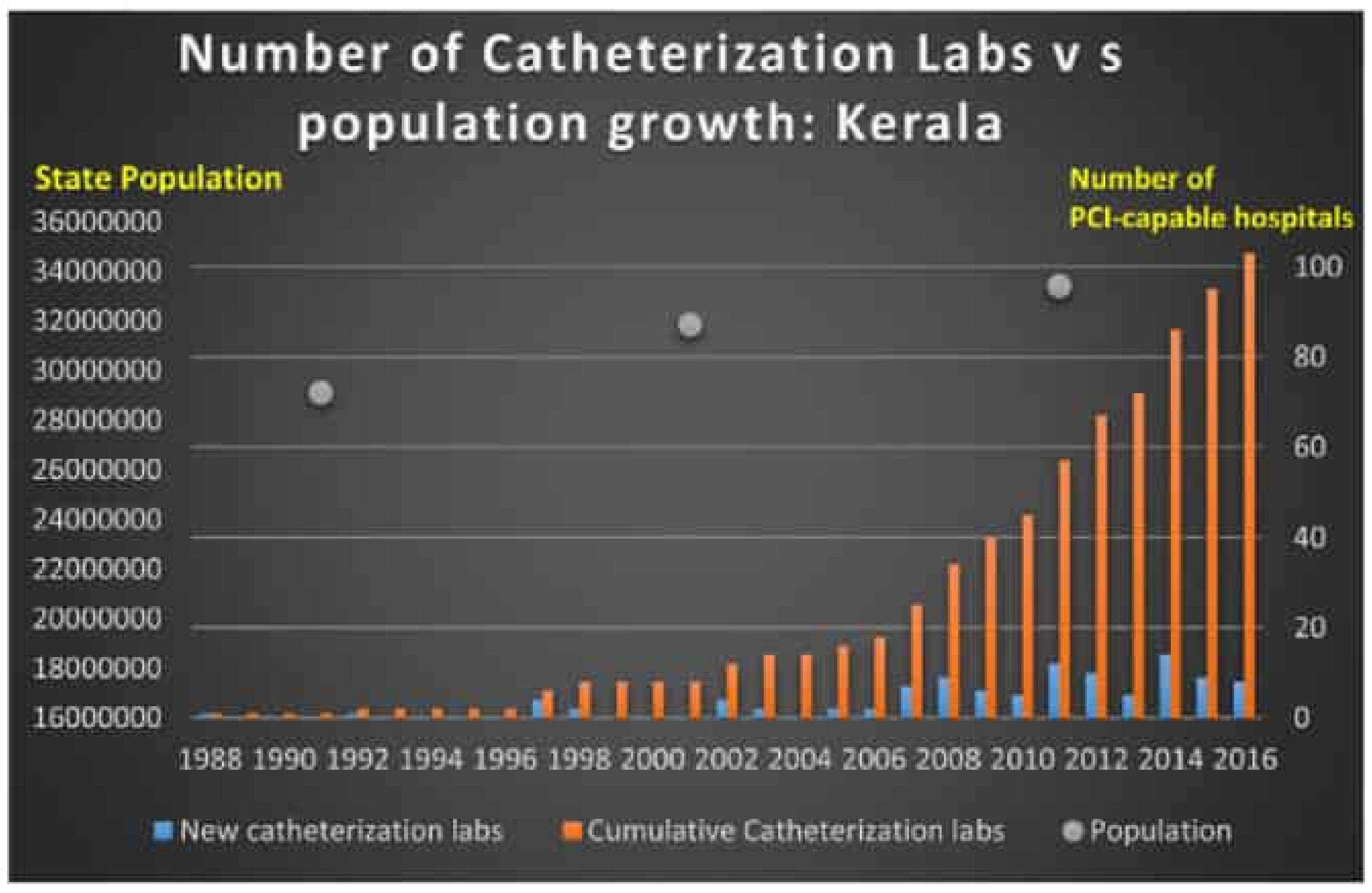

Fig. 2. Increase in the number of catheterization-lab equipped hospitals versus population growth, in Kerala, between 1988 and 2016.

PCI-capable hospital. The districts of Alappuzha and Ernakulam had the largest proportion of the population living within half-an-hour travel distance of a PCI-capable hospital, at 93.23% and 92.85% respectively. Eight out of 14 districts had more than 90% population having timely (within 1 h) access to some mode of reperfusion therapy for STEMI, either thrombolysis and/or primary PCI. As shown in Fig. 3, thrombolysis was the most accessible mode of reperfusion for more than a third of the population in 4 northern districts including Kasaragod, Kannur, Wayanad and Kozhikode. The districts having the largest proportion of the population with no timely access to reperfusion included Kasaragod (48.42%), Idukki (28.72%), Wayanad (19.47%) and Pathanamthitta (19.28%). Fig. 4 depicts the district-wise population access to timely reperfusion in terms of absolute number of people.

As shown in Fig. 5, in Kerala, 69.84% of the population resided within half-an-hour travel distance from a PCI-capable hospital (the green zone). Outside this green zone, 21.87% of the population had access to a thrombolysis-capable hospital within 1 h travel time. This included the population residing in areas within 1 h travel distance of a non-PCI-capable hospital offering thrombolysis alone (blue zone) and those residing within a travel distance of half-an-hour to 1 h of a PCI-capable hospital (yellow zone). The remaining 8.28% of the state population had no timely access to reperfusion therapy (red-zone) and would have had to travel more than an hour to access a reperfusion-capable hospital. The

Table 1
Geographical distribution of PCI-capable hospitals across various districts of Kerala.

District/state	Population	Geographical area (km^2)	Number of PCI-capable hospitals	Number of PCI-capable hospitals per million population
Alappuzha	2,127,789	1415	3	1.41
Ernakulam	3,282,388	3063	20	6.09
Idukki	1,108,974	4356	2	1.80
Kannur	2,523,003	2961	3	1.19
Kasargod	1,307,375	1989	0	0
Kollam	2,635,375	2483	9	3.41
Kottayam	1,974,551	2206	8	4.05
Kozhikode	3,086,293	2345	10	3.24
Malappuram	4,112,920	3554	8	1.94
Palakkad	2,809,934	4482	7	2.49
Pathanamthitta	1,197,412	2652	5	4.17
Thiruvananthapuram	3,301,427	2189	14	4.24
Thrissur	3,121,200	3027	12	3.84
Wayanad	817,420	2130	2	2.45
Kerala	33,406,061	38,852	103	3.08

Table 2
Geographical coverage of reperfusion-capable hospitals and population access to these hospitals across various districts of Kerala.

District/state	Percentage of geographical area covered			Percentage of population having access to reperfusion		
	Within half an hour travel distance from PCI capable hospitals (green zone)	Within 1 h travel distance from thrombolysis capable hospitals (yellow + blue zones)	More than 1 h travel distance to a reperfusion capable hospital (red zone)	Within half an hour travel distance from PCI capable hospitals (green zone)	Within 1 h travel distance from thrombolysis capable hospitals (yellow + blue zones)	More than 1 h travel distance to a reperfusion capable hospital (red zone)
Alappuzha	87	11.57	1.43	93.23	5.32	1.45
Ernakulam	82.16	17.75	0.08	92.85	7.05	0.10
Idukki	32.74	23.28	43.98	47.45	23.83	28.72
Kannur	36.75	45.82	17.43	50.04	39.50	10.46
Kasargod	0.09	58.67	41.24	0.11	51.47	48.42
Kollam	54.3	22.68	23.02	83.85	10.89	5.26
Kottayam	68.46	31.36	0.18	69.07	30.79	0.14
Kozhikode	33.14	45.83	21.03	50.22	38.25	11.53
Malappuram	56.01	27.66	16.33	77.03	18.29	4.68
Palakkad	43.94	29.62	26.44	65.9	27.66	6.44
Pathanamthitta	28.33	18.52	53.15	61.77	18.95	19.28
Thiruvananthapuram	59.26	26.45	14.29	80.95	13.67	5.38
Thrissur	69.67	18.99	11.34	86.8	10.68	2.52
Wayanad	28.64	51.19	20.16	30.02	50.51	19.47
Kerala	47.94	29.91	22.15	69.84	21.87	8.28

All figures are given in percentages.

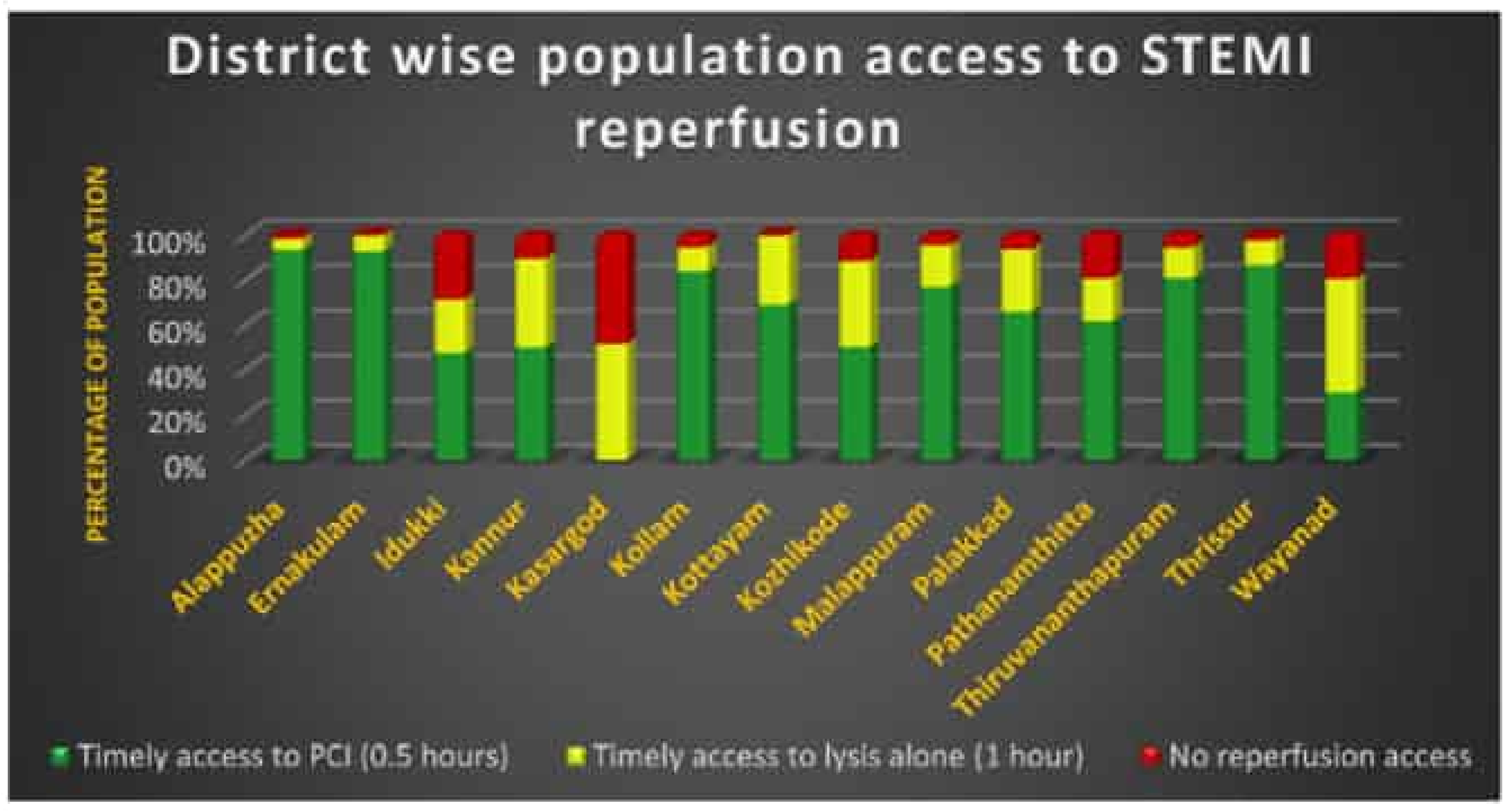

Fig. 3. District wise population access to STEMI reperfusion, for the state of Kerala. Green: proportion of population having timely access to PCI-capable hospitals (travel time <0.5 h), yellow: proportion of population having timely access to thrombolysis (travel time <1 h), and red: proportion of population having no timely access to thrombolysis (travel time >1 h). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

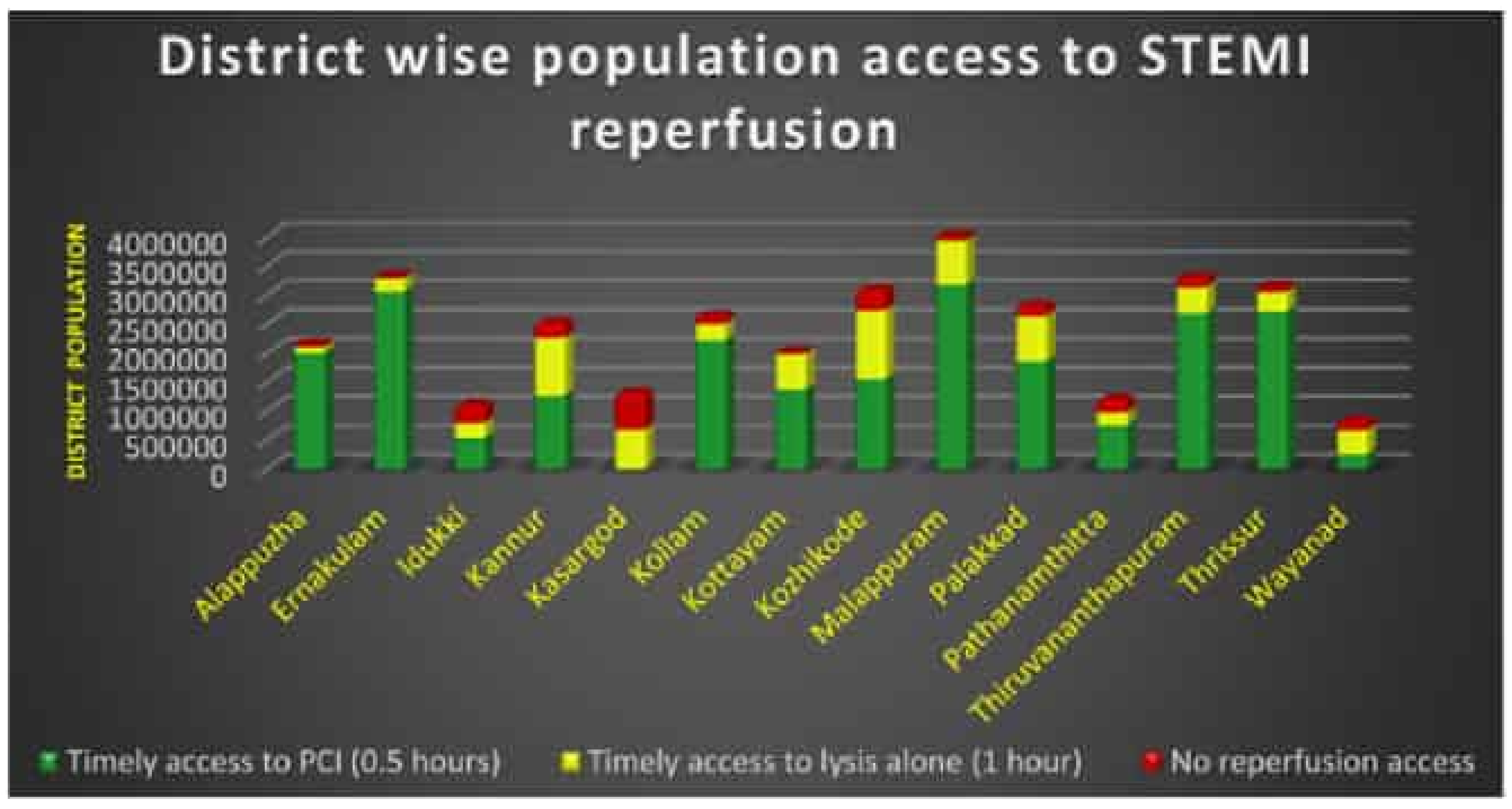

Fig. 4. District wise population access to STEMI reperfusion, for the state of Kerala. Green: number of people having timely access to PCI-capable hospitals (travel time <0.5 h), yellow: number of people having timely access to thrombolysis (travel time <1 h), and red: number of people having no timely access to thrombolysis (travel time >1 h). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

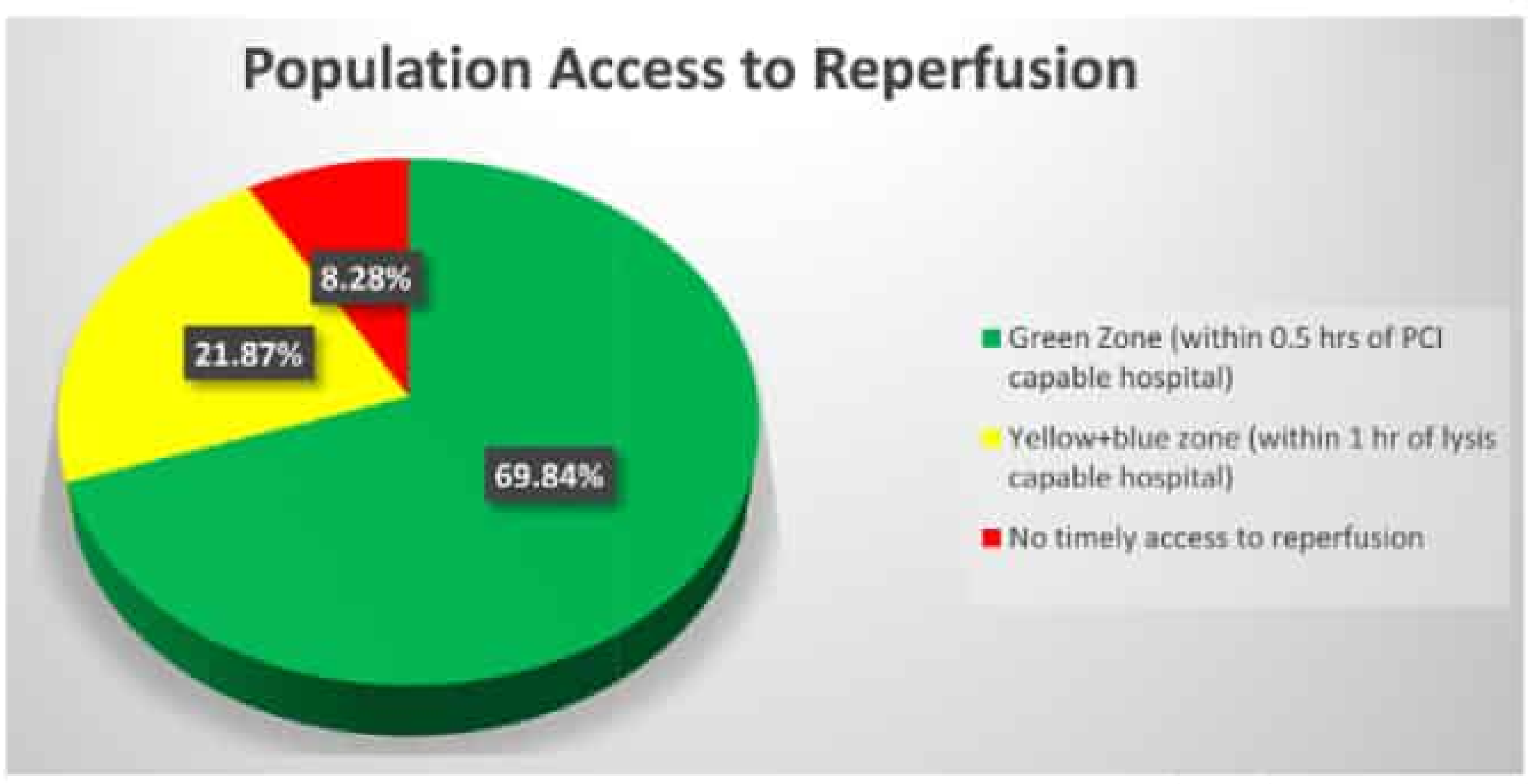

Fig. 5. State level population access to various modes of reperfusion, Kerala. Green: proportion of population having timely access to PCI-capable hospitals (travel time <0.5 h), yellow: proportion of population having timely access to thrombolysis (travel time <1 h), and red: proportion of population having no timely access to thrombolysis (travel time >1 h). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

corresponding geographical area coverage has been mapped in Fig. 6 and enumerated in Table 2.

4. Discussion

Only a minority of STEMI patients in India undergo timely reperfusion.[4,11] Contemporary Indian state-wide registries have shown that only 35.6–41.6% of STEMI patients receive thrombolysis, and a much smaller number (0.9–12.9%) receive percutaneous coronary interventions.[4,12] The median pre-hospital delays were unacceptably large, at 300–450 min across various studies.[3,12] Delay in time to thrombolysis after hospital arrival was also common.[3] Identifying barriers to timely reperfusion should be at the heart of quality improvement measures to improve outcomes in STEMI.

GIS based modeling have been used in a number of developed countries to quantify spatial access to health care services, before and after an acute coronary syndrome.[13–15] A majority (71%) of the Australian population resided within 1 h travel distance of a hospital with a catheterization laboratory.[15] Similarly, as on 2006, 79.9% of the adult U.S. population lived within 1 h travel distance of a PCI-capable hospital.[13] In Alberta, Canada, 69.9% of the adult population had access to a cardiac catheterization facility within 90 min travel time.[16] The southern Indian state of Kerala compares favorably with these developed countries in terms of population access to PCI-capable hospitals. Even with a stringent access time cut-off of 30 min, a majority (69.84%) of the population of Kerala had timely access to a catheterization facility.

Why is it that in spite of reasonable population access to PCI-capable hospitals only a minority of patients presenting with STEMI, in Kerala, achieve timely reperfusion? For patients presenting with STEMI, good access to reperfusion-capable hospitals is one of the prerequisites to improving timely reperfusion rates. Nonetheless, at a population level, good access in itself does not result in reduced pre-hospital delays. Population access to timely reperfusion can be improved by adopting various additional strategies. These strategies include community based interventions to enable patients recognize symptoms of STEMI early, improving the accessibility and quality of EMS services, using pre-hospital triage,[17,18] developing pre-hospital fibrinolysis capabilities, creating catheterization labs in remote hospitals, adoption of a pharmaco-invasive strategy in peripheral hospitals, EMS bypass of urban hospitals without PCI facilities[19] and widening the coverage of government sponsored health insurance schemes.[20] As shown in our analysis, a vast majority (90.3%) of PCI-capable hospitals were in the private sector. This inequity in the allocation of resources between private and public sectors will create barriers to accessing STEMI reperfusion, in the absence of a statewide government insurance scheme covering primary PCI.

While it is feasible to adopt the door-to-balloon time as the key performance indicator for institutions delivering primary PCI, at a national level this may not translate into a reduction in the in-hospital STEMI mortality rates.[21] Various systems of STEMI care have implemented community-based patient transfer protocols to achieve sustained reduction in different components of the total-ischemic-time.[22] Hospitals and EMSs participating in the reperfusion of STEMI patients should record and monitor time delays in order to continually assess processes of care and its relation to outcomes in patients presenting with STEMI.[23] Fibrinolysis should be achieved in ≤30 min for patients presenting to a non-PCI capable hospital initially, if the first medical contact (FMC)-to-device time is expected to be ≥120 min.[24] For such patients, if FMC-to-device time is expected to be <120 min, immediate transfer to a PCI-capable hospital is indicated, with an aim to achieve a FMC-to-device time of ≤90 min. For early presenters (within 2 h of symptom onset) and patients presenting directly to PCI-capable hospitals, FMC-to-device time of ≤60 min is preferred.[23] At an individual level, shorter patient-specific door-to-device times are consistently associated with lower mortality rates over time.[25] But, by focusing on the door-to-device time alone, one fails to take into account the significant duration of ischemia that exists prior to the FMC and the substantial rates of pre-hospital mortality.[26] While designing quality improvement initiatives to

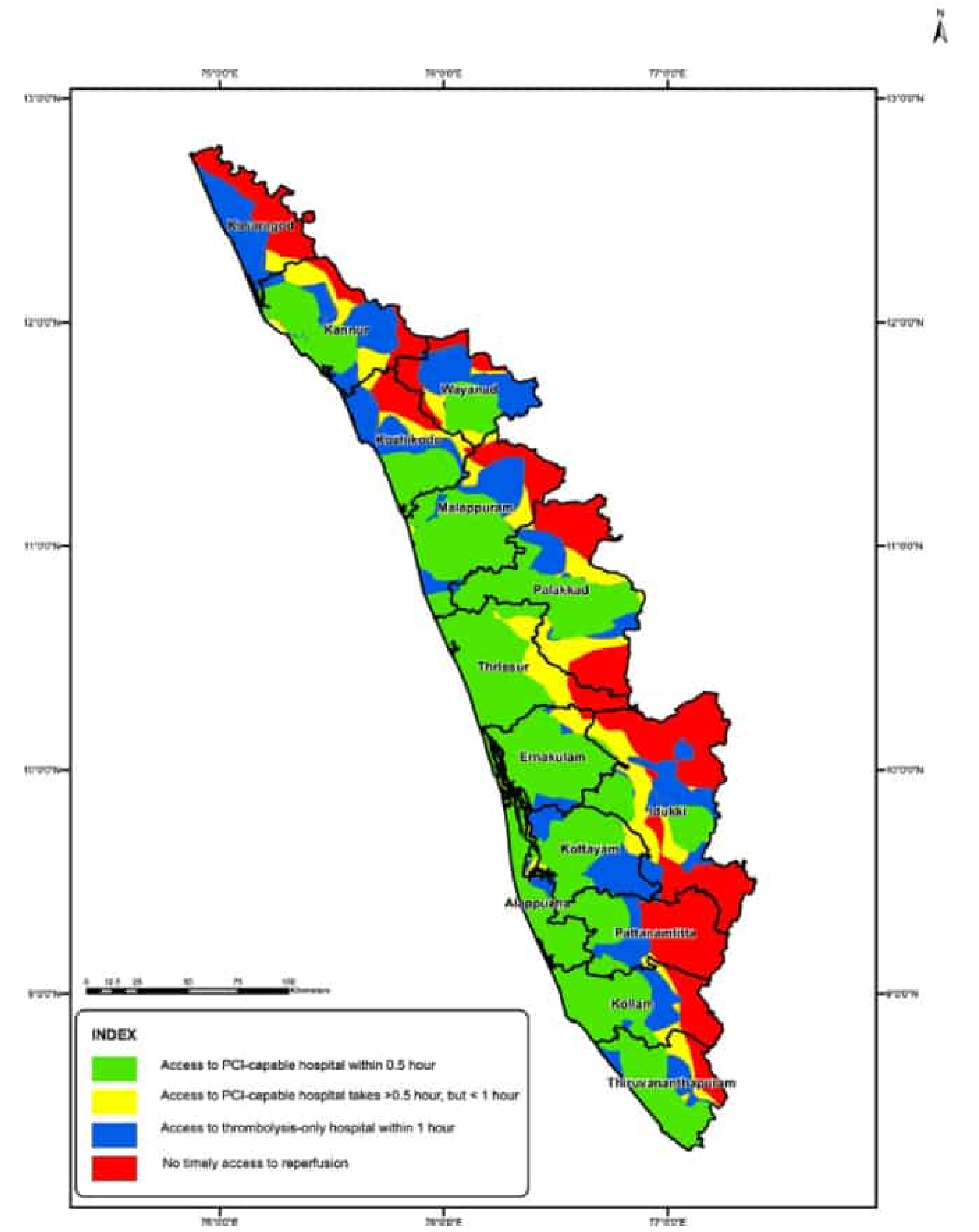

Fig. 6. GIS based map of Kerala, depicting the level of access to various modes of STEMI reperfusion.

achieve a substantially lower STEMI mortality rate, at a population level, total-ischemic-time may be the correct metric to focus on.[21,26] Pre-hospital delay, being the longest component of total-ischemic-time in Indian hospitals,[27] naturally becomes the focus point of quality improvement initiatives. Additionally, public reporting of key performance indicators may help achieve shorter total-ischemic-times and improve outcomes.

India has been slow to adopt systems of STEMI care, even though there has been some recent initiatives.[6] One of the reasons behind this reluctance could possibly be the level of fragmentation of the health care infrastructure. India does not have a national public health policy for the management of STEMI. In urban and sub-urban areas, patients with STEMI often make first medical contact at a non-reperfusion-capable hospital. These patients are often faced with the option of choosing from a number of PCI-capable hospitals, all within 1 h travel distance, since the PCI-capable hospitals are often clustered in the urban areas. While the simplest option is to transfer the patient using EMS to the nearest PCI-capable hospital, the choice is often complicated by a number of factors. In the Indian setting, patients may often choose the PCI-capable hospital based on the perceived quality of care and the level of affordability. Hence, it is not rare for a non-reperfused STEMI patient to be transferred to a larger but far-off private hospital, or a distant government hospital, bypassing a number of smaller PCI-capable hospitals. This can result in significant delays. A likely solution to the problem is to have a regional 24 × 7 STEMI coordinating center and to restrict government funding to PCI procedures performed in hospitals within a pre-specified distance from the location of first medical contact. However, larger volume hospitals may have better outcomes with primary PCI.[28–30] Therefore, strategies to promote sub-urban low-volume PCI-capable hospitals are questionable.

Most of the studies have looked at 1 h travel distance to assess accessibility to primary PCI.[14,15] Following acute onset of chest pain most Indian patients do not use EMS to reach the point of first medical contact.[3,4] Even if they did access EMS, proper resuscitation systems and trained staff may not available on many land ambulances. Hence, in many cases, shifting a patient with STEMI to a PCI-capable hospital is done under sub-optimal conditions. Therefore, in our model, we limited the transport time from the location of onset of chest pain to arrival at a PCI-capable-hospital to 30 min. Within this green zone primary PCI should be established as the preferred choice of reperfusion, with a benchmark FMC-to-device time of ≤90 min. Patients presenting within 2 h of symptom onset, and those presenting directly to PCI-capable hospitals should undergo primary PCI within 60 min of FMC.[23] Thrombolysis for patients residing in the green zone should be considered only if there are logistic issues to achieving these benchmarks with primary PCI and, additionally, in the absence of contra-indications, if fibrinolysis can be achieved with an effective agent within 30 min of FMC. For patients in the blue zone, who have access to thrombolysis capable hospitals within 1 h travel distance, the choice of reperfusion has to be individualized. In yellow and red zones the preferred choice of reperfusion would be pre-hospital thrombolysis, directed by a regional 24 × 7 STEMI coordination center, followed by transfer to a PCI-capable hospital, to achieve a pharmaco-invasive strategy. A majority of patients with no timely access to reperfusion live in remote areas (red zone), like the hilly terrain of districts like Idukki, Wayanad and Pathanamthitta. It is not feasible to start cardiac catheterization laboratories in these areas since the population density is less. Tele-medicine capabilities should be leveraged to achieve round the clock triage of patients presenting with chest pain in the red zones/remote areas.

This study has certain limitations. First, we have used historical travel times based on Google navigation systems for our analysis. Traffic congestion may be highly variable, resulting in changes in the actual travel times achieved on ground. The available regional road datasets that depict road types, posted speed limits and traffic estimates have their own limitations. Also, there may be significant differences in the speeds clocked by private vehicles and ground ambulances. However a majority of Indian patients use private vehicles to access hospitals for STEMI care.[3] Also, we used a road network analysis instead of using Euclidean or "straight-line" distance to locate travel distance. Second, we calculated the population covered by various modes of reperfusion at the block level, based on the proportion of geographic area covered. Locating population centers with a higher spatial resolution would have increased the accuracy of the analysis. Third, there is no regional database of acute care hospitals. While every effort has been taken to collate a complete list of acute care hospitals, there is a possibility that we may not have identified an occasional remote hospital that may be offering thrombolysis. Additionally, the health care infrastructure in Kerala is changing fast with more and more peripheral hospitals starting catheterization units. Hence any such analysis will have to be updated frequently to stay relevant. Finally, since this analysis was limited to the state of Kerala, we did not take into account the fact that a number of people in the border districts may access health care facilities in neighboring states. For example, the population of Kasaragod is likely to access health care facilities in Mangalore, Karnataka, for STEMI care. We believe that above factors are likely to make our estimate of population coverage a conservative one. Nonetheless, our study is the first attempt in India to address the issue of population access to cardiac healthcare infrastructure. We have been able to conclusively show that a majority of the population of Kerala had timely access to PCI-capable hospitals.

Any system of care for STEMI reperfusion should address the cultural factors that prevent patients from accessing reperfusion capable hospitals, preferably utilizing EMS, in a timely manner. GIS based mapping of STEMI care accessibility would help align health education initiatives to the locally available health-care resources. Public awareness campaigns should clearly convey how to identify symptoms of myocardial ischemia and stress the importance of accessing EMS at the earliest. Enhanced stakeholder participation in quality improvement initiatives, including developing standardized community-based, GIS-delineated, patient transfer algorithms to achieve timely reperfusion of STEMI, is a vital step in improving the population level STEMI outcomes.

5. Conclusions

A majority of the population of Kerala had timely access to PCI-capable hospitals. Hence, in Kerala, primary PCI should be the key strategy while devising a system of STEMI care. Less than a quarter of the geographical area of the state had no timely access to any mode of reperfusion. Pre-hospital thrombolysis, en route to a PCI-capable hospital, could be the preferred strategy for STEMI reperfusion in pre-specified rural and suburban areas. Systematic mapping of Indian states in terms of access to STEMI reperfusion, using GIS, may help devise protocols to achieve seamless transfer of patients to reperfusion capable hospitals. Such regionalization of STEMI care would help regulate allocation of health-care resources, and develop organizational synergies to achieve better access to reperfusion, especially in remote areas.

Conflicts of interest

The authors have none to declare.

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