

Spatial Inequity in Access to Intensive Care Unit Beds at Regional Level in Italy

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Abstract. The high demand of hospitalization in the intensive care units (ICUs) during the first wave of the COVID-19 outbreak brought out the critical issues of the limited capacity of the regional systems to deal with high patient inflows in a short period of time. In this view, a rapid and efficient reallocation of resources is one of the main challenges to be addressed by regional systems to prevent overload and saturation. Aim of this study is to assess the spatial accessibility of ICU beds in the 20 Italian regions to capture the equity distribution of critical care services across the country. This analysis may contribute to gain a deeper understanding of the allocation of health resources. It can provide input for policy makers in view of a possible reorganization of the national system in terms of both its preparedness for emergency period and routine capability.

Keywords. Spatial accessibility, intensive care unit, hospital beds, Italy

1. Introduction

The severe diffusion of COVID-19 that has affected Italy and in particular its northern regions since the beginning of March 2020, resulted in a high demand of hospitalizations in particular in the intensive care units (ICUs) [1]. While all hospital wards struggled with an exceptional workload, the ICUs were particularly stressed given that the majority of them in the northern part of the country saturated or nearly saturated their capacity [2]. At the moment, even if the second wave started more than five months ago (i.e. September 2020), around 26% of ICU beds in the country are occupied by COVID-19 patients, with important differences across regions spanning from 5% in Basilicata to 41% in Umbria [3]. This high demand of intensive care services and hospitalization brought out all the critical issues of the limited capacity of the regional health systems to deal with high patient inflows in a short period of time. In this perspective, one of the main challenges would be to rapidly and efficiently assign and reallocate appropriate resources, such as medical professionals, equipment, hospital beds to face overload and saturation [2]. Usually, the main indicator adopted to determine the capacity of hospitals is limited to the number of beds per 100000 inhabitants, computed at regional level. However, this indicator considers only the availability of adequate health care resources within each region but does not consider a fundamental aspect of universal care: the accessibility in terms of travel distance.

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Availability and accessibility are commonly merged under the term spatial accessibility [4], and relevant inequities at national and regional level were known long before the COVID-19 pandemic [5].

Within this context, aim of this study is to assess the spatial accessibility of ICU beds in the 20 Italian regions under the lens of inter- and intra-regional variability. This can help to capture the level of equity in the provision of critical care services across the country. In view of a possible rethinking of the organization of the Italian as well as the regional health systems in terms of both its preparedness for emergency period and routine capability, this paper can contribute to gain a deeper understanding of the allocation of health resources providing input for policy makers in the basis of the principles of accessibility and continuity of care.

2. Materials and methods

The accessibility index (AI) is computed applying the enhanced two step floating catchment area methodology (E2SFCA) [6]. This well-established method is based on a gravity model which considers the declining probability to access to a health care service with increasing travel distance. It is based on the following formula:

$$AI_i = \sum_j R_j W_{ij} = \sum_j \frac{n_j}{\sum_i (P_i * W_{ij})} \quad (1)$$

Where i and j represent, respectively, the centroid of the municipality and the location of the hospital, n is the number of ICU beds and P is the resident population. The variable W represents the weighting distance between the hospital j and the municipality i . In this study we set the maximum catchment size to 120 minutes by car, which is in line with current literature regarding the inpatient sector [5]. The distance decay function $W_{ij} = f(d_{ij})$ that represents the declining probability that a patient that live in the municipality i will utilize the hospital j has been computed using the Gaussian fast decay function [7]. To compute the AI of each municipality two steps are performed: 1) for each hospital j the weighted hospital-to-population index (R_j) is computed as the ratio between the number of ICU beds and the population size of all municipalities within each hospital catchment (accounting for distance decay between 0 and 120 minutes); 2) the index R_j values from all the hospitals within the driving catchment from the municipality i are summed. For a detailed description of this methodology refers to the original work published by Luo et Qi [6].

The AI was computed on the basis of two information sources: 1) the website of the Ministry of Health [8] to gather data on hospitals and 2) the website of the Italian National Institute of Statistics (ISTAT) [9] to collect boundaries of both regions and municipalities as well as the resident population. Data analyzed in this study refers to the year 2017, the latest most outdated information currently published by the Ministry of Health. The geo-referencing of both hospitals and municipalities as well as the distance between them were computed using the API provided by the OSRM (Open Source Routing Machine) [10]. Results were analyzed and displayed using the open-source cross-platform desktop geographic information system (GIS) application QGIS [11].

3. Results

The map shown in Figure 1 highlights the AI computed for each municipality in the year 2017 also reporting the geo-localization of each hospital using black circles. Looking at the map it is clear that regions distributed the hospitals differently with the majority of hospitals located in cities with high density population. To analyse this different distribution of ICU beds over the territory at regional level, Table 1 summarizes the average and the standard deviation values of the AI also reporting, for each region, the number of beds and hospitals. To facilitate the comparison all variables are normalized per 100000 inhabitants.

Looking at the capacity of each region, the number of beds are not strictly related to the AI. In particular, six regions (Campania, Emilia-Romagna, Lazio, Lombardia, Piemonte and Veneto) report a higher AI than the number of beds. In some of them (Campania, Lazio, Lombardia and Piemonte) this pattern can be related to the location of ICU beds that are generally concentrated in high populated zones of the territory, leaving rural areas not served by this critical care service. Similar results is shown in Emilia Romagna and Veneto where hospital beds are mainly distributed around the cities with higher population than within the rural part of the territory. From this perspective, when analysing the distribution of beds, it is also important to consider how many hospitals are located in each region. As shown in Table 1, Veneto, Lombardia and Emilia Romagna report the lowest number of hospitals per population, respectively 0.31, 0.39 and 0.43.

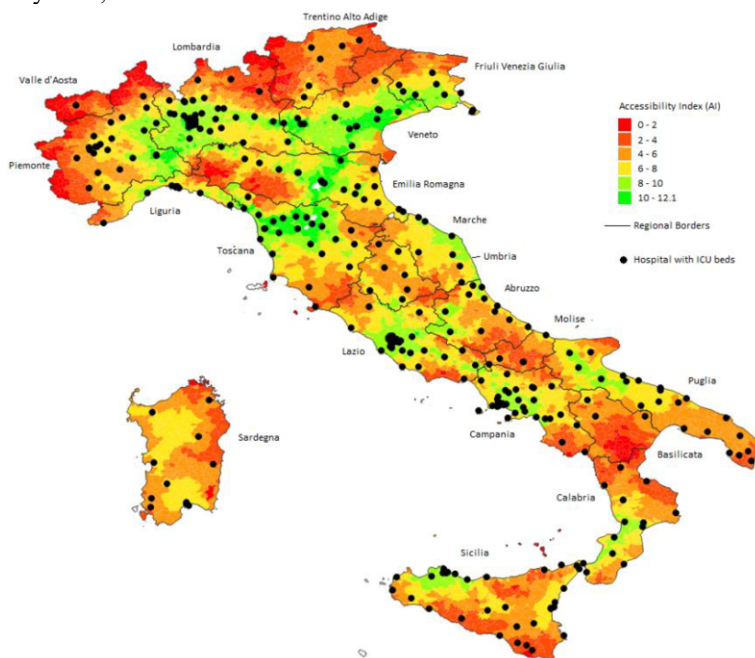


Figure 1. Analysis of accessibility index (AI) for intensive care unit (ICU) beds in the 20 Italian regions

The remaining 13 regions report a low AI value in compare to the number of available beds. In some of them (Basilicata, Liguria, Molise and Valle d'Aosta) this can be explained by the fair distribution of ICU beds over the territory not privileging high density areas. This gap between theoretical availability and practical accessibility

of resources can be also explained considering the location of the hospitals and the opportunity of patients to be admitted in facilities outside the region of residence. This is the case of Molise that concentrates the majority of its ICU beds in hospitals located at its borders. Also for this reason Molise is the region with the highest percentage of patient attracted from other regions (around 27%), as reported in [12].

Table 1. Accessibility index (AI) reporting the average and the standard deviation (StDev) for each region for the year 2017. Number of beds and hospitals are also reported. All variables are normalized per 100.000 inhabitants.

Region	# Hospitals	# ICU beds	AI (Average)	AI (StDev)
Abruzzo	0.86	7.20	6.8	1.28
Basilicata	0.53	8.72	4.5	1.52
Calabria	0.75	7.15	6.3	1.88
Campania	0.63	7.64	7.8	1.23
Emilia-Romagna	0.43	7.75	8.1	2.00
Friuli Venezia Giulia	0.72	9.56	7.7	1.30
Lazio	0.58	8.50	8.5	1.75
Liguria	0.75	12.22	7.6	1.36
Lombardia	0.39	7.08	8.4	1.69
Marche	0.47	8.49	7.7	1.04
Molise	1.67	11.69	4.9	1.36
Piemonte	0.55	6.63	6.7	1.70
Puglia	0.59	5.89	5.9	1.35
Sardegna	0.75	7.47	5.4	1.41
Sicilia	0.73	6.97	6.4	2.31
Toscana	0.71	9.83	9.3	2.25
Trentino-Alto Adige	0.54	6.07	4.8	1.39
Umbria	0.74	7.33	6.1	0.89
Valle d'Aosta	0.73	7.29	2.9	1.09
Veneto	0.31	9.02	9.1	1.79
Italy	0.56	7.78	7.6	1.72

Another important aspect to be analysed is the intra-regional variability that provides an important indicator of equity distribution of health resources within the relevant region. Looking at the map (Figure 1) it is clear that different areas of the country are far away from providing critical care services adequately (i.e. reported in red). The majority of them, of course, are located in the rural part of the country and covers only a limited number of citizens. However, the standard deviation reported in Table 1 specifies that a high variability is displayed in almost all regions. As previously described, the location of the majority of the hospitals contributes to different levels of inequalities in the provision of critical care services in the majority of the regions. This is true not only considering the concentration of beds close to the main cities (e.g. Campania, Lombardia, Lazio, Piemonte) but also it may depend on the number of hospitals available and how beds are distributed within them. For instance, this is the case of Veneto, Lombardia and Emilia Romagna where the number of hospital per 100000 inhabitants are 0.31, 0.39 and 0.43, respectively resulting in a high level of variability.

4. Discussion and Conclusions

Distribution of hospital beds in a specific territory is generally monitored through the number of beds per population. However, this indicator limits the analysis to the availability of beds leaving out the level of accessibility that is a fundamental aspect for

the provision of prompt and equal critical care services. Moreover, the spatial accessibility index provides a more comprehensive and robust analysis given that it also takes into account the inter-regional mobility that, in Italy, represents more than 7% of the total number of hospitalizations [12]. Inequities and the heterogeneous distribution of ICU beds in each region have been analysed comparing the accessibility index with the crude number of beds per population. The result of this analysis highlights two main patterns of hospital distribution over the territory in the different Italian regions. On the one hand, regions with high density cities (e.g. Lombardia and Lazio) tend to concentrate ICU hospitals and beds in high populated zones, leaving rural areas not served by this critical care service. On the other hand, small regions such as Molise and Basilicata fairly distributed ICU beds and hospitals over the territory not privileging high density areas and localizing them at their borders resulting in a high level of inflow mobility rate, as detailed in [12].

Looking at the intra-regional variability of AI it emerged that different areas of the country in almost all regions are far away from providing critical care services adequately (i.e. reported in red in Figure 1). These different levels of inequality can be explained by the concentration of ICU beds that are distributed in a limited number of structures, such as in three northern regions: Veneto, Lombardia and Emilia Romagna.

Further analysis may be considered to extend the availability and accessibility of critical care services with primary care and specialist services that can play an important role in the care of patients, especially in this pandemic period. This can provide a comprehensive view of the availability and accessibility of the different health services over the territory. This that can help to reorganize and rethink the Italian as well as the regional health systems in terms of both its preparedness for emergency period and routine capability.

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