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Spatial analysis and factors associated with transcatheter aortic valve implantation in Portugal: a retrospective analysis from 2015 to 2017

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ABSTRACT

Objectives To identify the factors associated with transcatheter aortic valve implantation (TAVI) use of TAVI in inpatients with aortic stenosis (AS) in Portugal and its geographical distribution.

Methods A quantitative, observational and retrospective study using the Portuguese National Health Service inpatient discharge database from 2015 to 2017. Surgical aortic valve replacement (SAVR) and TAVI procedures were selected using the International Classification of Diseases. First, we mapped the yearly age-standardised rate for each procedure using QGIS. Then, we performed χ^2 tests, independent t-tests and logistic regressions to study the factors associated with TAVI use.

Results From 2015 to 2017, 8398 hospitalisations were selected, 88.5% SAVR and 11.5% TAVI. From 2015 to 2017, SAVR use increased in the Northern region and decreased in the Lisbon region, while the opposite was observed for TAVI. TAVI was performed among the most complex (p<0.001) and older patients (the mean (SD) age for SAVR was 70 (±11) years old and 81 (±7) years old for TAVI, p<0.001). The results for the logistic regressions showed that, more recent hospitalisations, being older, living in the Lisbon region and having a higher Charlson Comorbidity Index was associated with an increased likelihood of undergoing TAVI (p<0.001).

Conclusions TAVI increased over the years. TAVI is more often performed in more severe patients as an alternative to SAVR with similar discharge outcomes. These results suggest the existence of geographic disparities in the availability and access to healthcare services and technologies.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study is highly representative of the national real practice as it used a large database of all inpatient data for the Portuguese National Health Service hospitals, from 2015 to 2017.
⇒ Identifying geographical differences in aortic stenosis (AS) treatment might contribute to designing informed policies to improve the healthcare systems.
⇒ This is a secondary database, collected for administrative purposes, which was not intended for academic research and excludes the private settings.
⇒ We cannot infer causality with the present study design and data.
⇒ The Charlson Comorbidity Index is represented by a specific group of comorbidities commonly used in observational studies; other important comorbidities, which might influence AS severity and medical decision on therapeutic choice, might not be considered.

INTRODUCTION

Aortic Stenosis (AS) is a pathological condition characterised by the narrowing of the cardiac aortic valve, which has severe consequences for a patient's quality of life, including loss of mobility, decreased productivity and limitations in daily living activities.[1 2] It is a significant public health problem worldwide, particularly in developed countries, due to increasing life expectancy, and it affects 2.3% of the world population.[3 4] The prevalence of AS in the Portuguese population varies from 3% to 23%,[1] and the estimated number of patients eligible for treatment is of 32 000 patients.[5]

This condition can result in death if not appropriately treated, particularly in most severe cases. Without treatment, approximately half of patients would die within 1–2 years.[6] Also, half to one-third of patients might be asymptomatic at the time of diagnosis.[7] Additionally, the survival prognosis for every three out of four patients is generally of 3 years, after symptoms onset.[8] Although asymptomatic patients usually present a low rate of complications, when symptoms are already installed, the absence of follow-up would result in a very adverse prognosis.[9]

Until the beginning of the 21st century, surgical aortic valve replacement (SAVR) was the standard procedure for AS treatment, and it was the only available surgical intervention.[8] Nevertheless, this therapeutic option was not possible in high-risk surgical cases, due to patient frailty and numerous comorbidities.[2 5]

In 2002, transcatheter aortic valve implantation (TAVI) emerged as a solution for individuals not eligible for SAVR, since it was a less invasive procedure. This technology represented an important innovation in the treatment of AS patients with high-risk surgical. TAVI has been shown in various clinical trials[1 10] to reduce all-cause mortality, cardiovascular disease and readmissions.[11] In Portugal, the records of the beginning of the use of this procedure date from 2007.[12]

In the forthcoming years, the use of TAVI is expected to increase. The reasons are: (1) AS is expected to become more prevalent due to the demographic transition and the ageing population observed worldwide.[3 4] Therefore, the need for treatment will also increase; (2) It is also likely that the technology will be used more extensively, expanding of the criteria for TAVI use (eg, for medium-risk or low-risk surgical patients). Thus, the number of individuals eligible for treatment will also increase.[13]

Despite the predictable rise in the use of technology, scientific evidence tells us that the incorporation of technologies is usually not done homogeneously.[14] Although technologies may improve people's health, lack of equitable access might perpetuate health disparities. Even in countries with universal access to healthcare, disparities in access may exist at the regional level. Hence, it is important to study the determinants of access to treatment and incorporation of technology to reduce this effect. This study aims to identify the geographical patterns and sociodemographic and clinical factors associated with TAVI use in inpatients diagnosed with AS in the Portuguese National Health Service (NHS) from 2015 and 2017.

MATERIAL AND METHODS

Quantitative, observational and retrospective study using the inpatient discharge database for the Portuguese NHS hospitals, from 2015 to 2017.

Data source

The Central Administration of Health Services and the Shared Services of the Ministry of Health jointly managed the inpatient database. All entries in the database had a unique identifier that was anonymised to ensure the confidentiality of the patients analysed. The database had information about primary and secondary diagnosis, age, gender, interventions performed, in-patient length of stay and area of residence.

This study was a secondary analysis of an existing database; thus, it does not fall within the definition of research involving human subjects. Nonetheless, the ethical principles governing health research were considered and anonymised information guaranteed data confidentiality.

The dependent variable was intervention type, and it was defined using the International Statistical Classification of Diseases and Related Health Problems (ICD), versions 9 (ICD-9) and 10 (ICD-10). The codes used to select SAVR procedure were the following: ICD-9—3521 and 3522; ICD-10—02RF07Z, 02RF08Z, 02RF0JZ, 02RF0KZ and X2RF032. For TAVI, we used the following ICD codes: ICD-9—3505 and 3506; ICD-10—02RF37H, 02RF37Z, 02RF38H, 02RF38Z, 02RF3JH, 02RF3JZ, 02RF3KH, 02RF3KZ, 02RF47Z, 02RF48Z, 02RF4JZ, 02RF4KZ, X2RF332 and X2RF432.[15] Then, it was dichotomised (SAVR=0 and TAVI=1).

The sociodemographic characterisation included variables, such as gender, age and place of residence. Additionally, inpatient clinical information, such as and type of admission (elective or non-elective admission), length of stay, destination after discharge, severity level (minor, moderate, major or extreme) and main and secondary diagnosis were considered in the analysis.

The primary and secondary diagnoses were used to compute the Charlson Comorbidity Index (CCI),[16] as presented in online supplemental appendix 1. The CCI is widely used in clinical practice to assess patient comorbidity level, as a proxy of patients' severity. According to the literature, it predicts long-term[17] and in-hospital[18] mortality. It can also be used to evaluate differences in diagnosis and prognosis between groups of patients sharing the same clinical diagnosis.[18] The CCI is a validated instrument, allowing the assessment of the burden of comorbidities and the measurement of patients' outcomes, particularly among AS patients.[19 20] Online supplemental appendix 2 presents the weights used to calculate the CCI. The CCI was analysed in two ways: as an index, and as a categorical variable (cut-off point≥3).[19 21 22] Additionally, the relation between procedures and the pathologies that compose the index were evaluated separately, as many of the pathologies that comprise the index are common among AS patients.

Spatial analysis

The age-standardised hospitalisation rate per year was then calculated using the direct method to compare population groups with different age structures[23] (online supplemental appendix 3). For standardisation, the total Portuguese population stratified by age was used. From the absolute number of each procedure, the procedure's prevalence per district and age group was calculated. This value was subsequently used to estimate the value of expected hospitalisations by age group. The standardised rate resulted from dividing the total number of expected cases by the standard population and multiplying by 100 000 inhabitants.

The age-standardised rate was mapped for the years analysed using QGIS Desktop V.3.22.7[24] software, using the shapefiles of the administrative map of Portugal available at http://dados.gov.pt,[25] to characterise the spatial distribution of TAVI and SAVR procedures, and their trends from 2015 to 2017.

For the spatial analysis, the TAVI and SAVR procedures were analysed according to the district of residence.[26] For the remaining statistical analysis, the place of residence was aggregated according to Nomenclature of

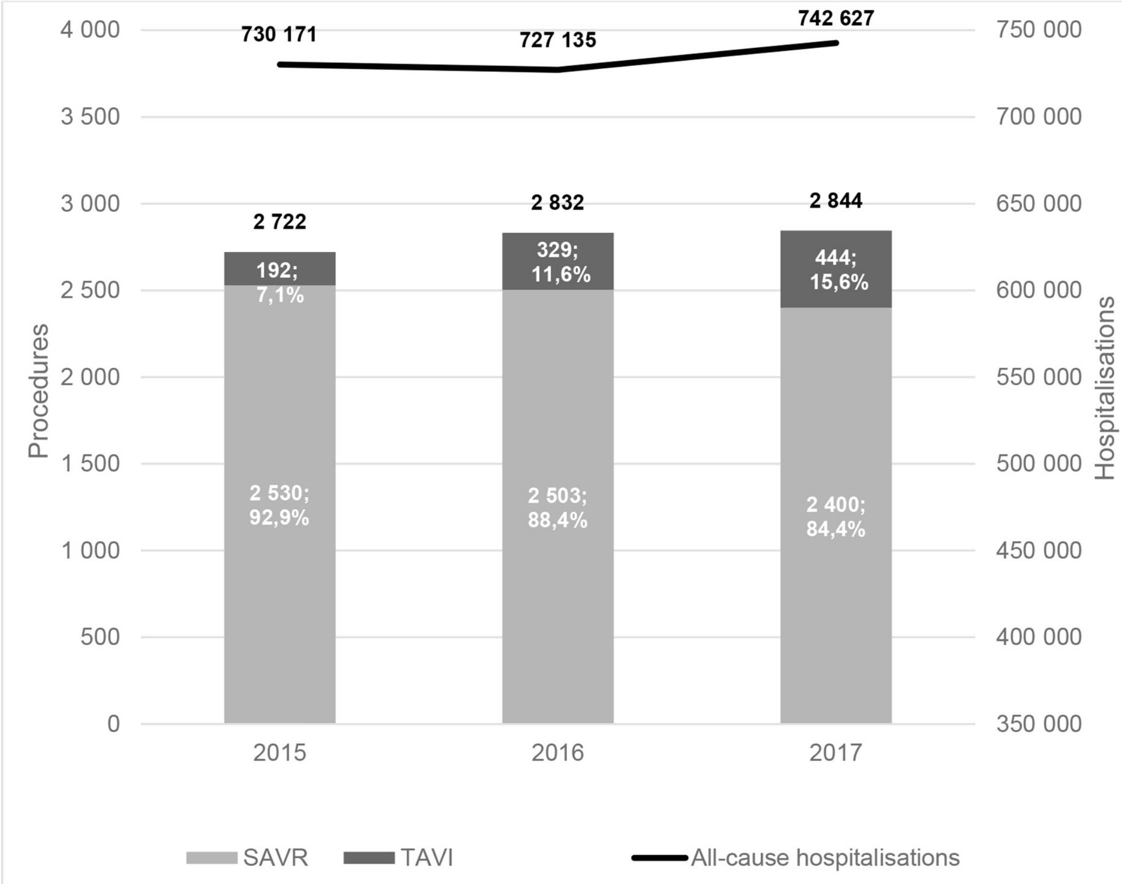


Figure 1 Annual number of hospitalisations, and procedures, in the Portuguese National Health Service, from 2015 to 2017. SAVR, surgical aortic valve replacement; TAVI, transcatheter aortic valve implantation.

Territorial Units for Statistics II classification,[26] due to the low number of district-level observations.

Statistical analysis

In the first stage, the χ^2 test, Fisher's exact test and independent t-tests were performed to measure the association between the procedures performed and the remaining variables. In the second stage, the adjusted and unadjusted OR using logistic regressions were computed to identify the association between TAVI and the explanatory factors, using significance level of 5% (two-tailed test). The analyses were performed using the Statistical Package for the Social Sciences (IBM SPSS Statistics) V.28.

Patient and public involvement

None.

RESULTS

Procedures distribution

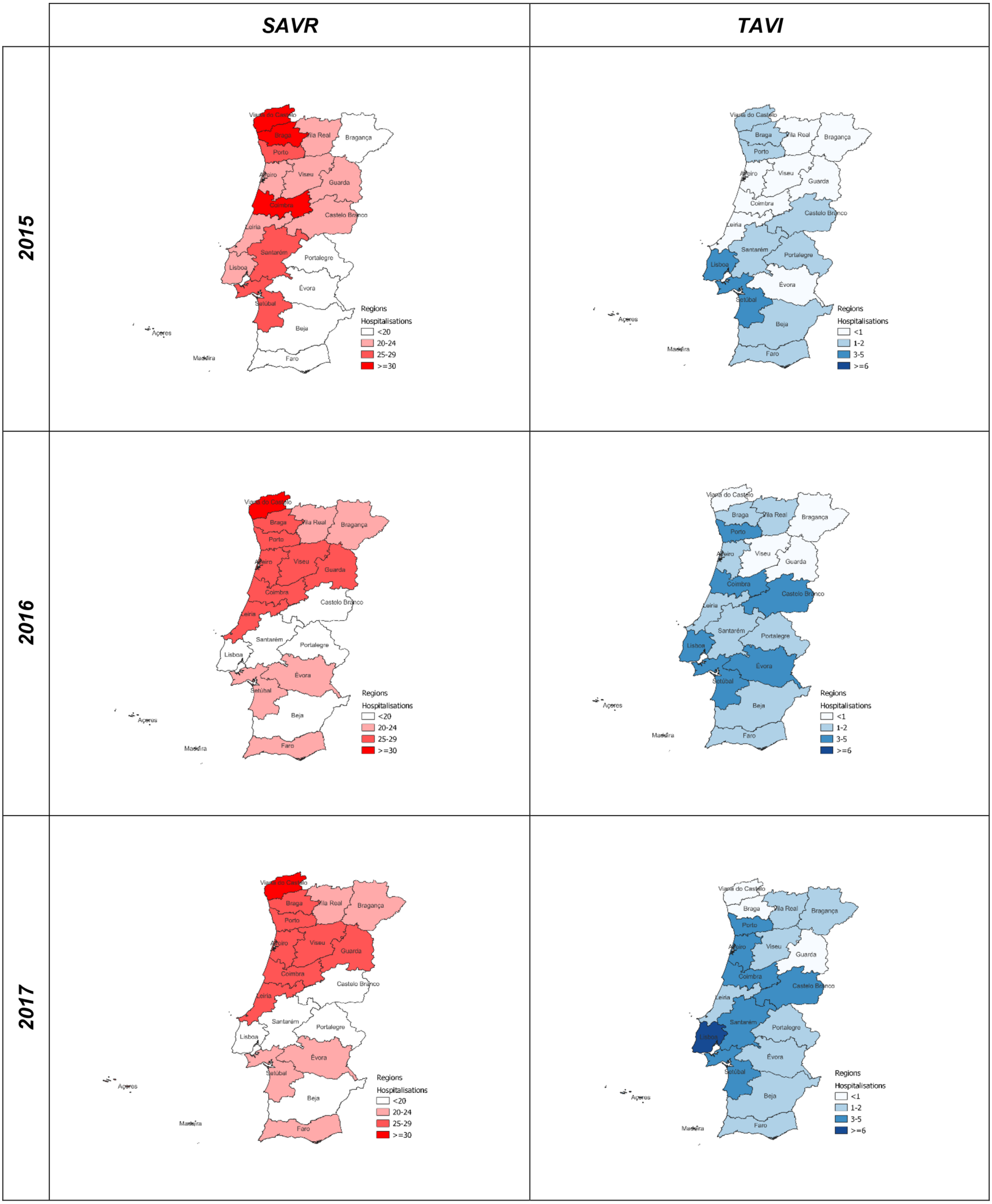
Between 2015 and 2017, 2 199 933 inpatients were admitted to NHS hospitals. From this, 8398 hospitalisations were analysed, corresponding to 0.38% of the total, 2722 (32.41%), 2832 (33.72%) and 2844 (33.87%), respectively, in 2015, 2016 and 2017 (figure 1). SAVR was performed in 7433 admissions (88.51%) and TAVI in 965 admissions (11.49%). TAVI showed an increasing trend, from 7.1% in 2015 to 15.6% in 2017. By contrast, the number of patients undergoing SAVR decreased by more than eight percentage points over the analysed period.

Spatial analysis

Figure 2 presents the geographical distribution of the age-adjusted hospitalisation rate by district, from 2015 to 2017. When analysing SAVR, the colour becomes darker in the Northern region over the years and becomes lighter in the Lisbon region. The opposite trend was observed among TAVI, where the colour became darker in the region around Lisbon.

Regarding TAVI, there was both a growth and a concentration of procedures performed. Most districts had an increase in TAVI use. The Lisbon district had the highest absolute difference (3.98), from 3.80 per 100 000 inhabitants in 2015 to 7.78 per 100 000 inhabitants in 2017. Lisbon and Setubal were among the three districts with the highest rates of TAVI per 100 000 inhabitants (3.91, 5.57 and 8.01 for Lisbon and 3.37, 4.34 and 5.18 for Setubal in 2015, 2016 and 2017, respectively). During this period, Viana do Castelo, Guarda and Braga districts had a negative absolute difference for TAVI.

SAVR increased in 11 districts and decreased in the other nine districts. From 2015 to 2017, the autonomous region of Madeira presented the highest absolute



Legend: The standardised rate resulted from dividing the total number of expected cases by the standard population and multiplying by 100,000 inhabitants.

Figure 2 Age-adjusted hospitalisation rates for SAVR and TAVI in Portuguese National Health Service hospitals by patients' district of residence, from 2015 to 2017. The standardised rate resulted from dividing the total number of expected cases by the standard population and multiplying by 100,000 inhabitants. SAVR, surgical aortic valve replacement; TAVI, transcatheter aortic valve implantation.

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difference (17.25) and Santarem had the highest absolute reduction (−7.18) in SAVR procedures. Braga and Viana do Castelo are two of the three districts with the highest SAVR rates (Viana do Castelo: 37.19: 35.17 and 31.53 per 1000 inhabitants; and Braga: 33.56; 33.17 and 30.20 per 1000 inhabitants). Braga and Viana do Castelo showed the highest SAVR standardised rate in 2017, and these same districts showed a higher reduction in TAVI.

Study population characteristics

SAVR patients were mostly men (56.9%), while TAVI patients were mostly women (55.4%) ($p<0.001$). The mean age among TAVI patients was higher than among SAVR (81 years old vs 70 years old, $p<0.001$). Most admissions were elective for both procedures, but non-elective hospitalisations were higher among TAVI than SAVR (13.1% vs 9.4%) (table 1). The Northern Region had the highest percentage of SAVR (41.20%), while the Lisbon region had the highest percentage of TAVI (46.30%). Both procedures had a comparable length of stay (13 days, $p=0.602$). The mortality was also similar for both procedures, with more than 80% of patients discharged home. Most admissions had moderate severity level (53.0% for SAVR and 47.6% for TAVI), but the minor severity was more expressive among SAVR (31.8%) than TAVI (27.8%). The CCI was higher among TAVI than SAVR (1.80 vs 1.33, $p<0.001$). Most individuals had between 0 and 2 points of the CCI (TAVI 83.8% vs SAVR 69.8%). The patients undergoing TAVI had more comorbidities or severe clinical conditions, represented by a higher percentage of individuals with CCI>3 (30.2% compared with 16.2% in SAVR, $p<0.001$). A distribution of the CCI by procedure is available in online supplemental appendix 4.

Overall, 7 of the 17 health conditions that comprise the CCI were not statistically significant associated with TAVI procedure. Most individuals were diagnosed with congestive heart failure (37.9% in TAVI, compared with 34.5% in SAVR, $p=0.041$). Additionally, the four conditions with the highest occurrence among individuals undergoing SAVR, were diabetes without chronic complications, peripheral vascular disease, and chronic pulmonary disease. As for individuals that underwent TAVI, the most prevalent conditions were kidney disease, diabetes without chronic complications and chronic pulmonary disease.

Factors associated with undergoing TAVI

The year of hospitalisation was associated with the likelihood of undergoing TAVI. The more recent hospitalisations had a higher likelihood of being TAVI, TAVI, considering 2015 as a reference (OR=2.87 (2.34–3.52) for 2017, and OR=1.68 (1.37–2.07) for 2016) (table 2). Older patients also had an increase in likelihood of undergoing TAVI: each additional year of age represented a 21% increase in the odds of undergoing TAVI (OR=1.21 (1.20–1.23)). The geographical location was associated with the procedure. In most of the regions was observed an increased likelihood of undergoing TAVI, when compared with the Northern Region of the country (OR=1.64 (1.29–2.08) for Centro and OR=1.84 (1.34–2.53) for Alentejo). In the Lisbon region, the odds of having TAVI were even higher, and patients living in this region had more than two times the likelihood of undergoing TAVI OR=2.62 (2.16–3.18). Additionally, individuals with higher CCI also showed an increased chance of undergoing TAVI, when compared with lower CCI (OR=2.55 (2.10–3.10)).

DISCUSSION

This study aimed to identify the factors associated with TAVI use in inpatients with AS in Portugal and its geographical distribution. The results showed an increasing trend in patients undergoing TAVI over the years ($p<0.001$). Being older, living in the Lisbon region and having a higher CCI were individual characteristics associated with an increased likelihood of undergoing TAVI procedure ($p<0.001$). There was a geographic concentration in the SAVR utilisation in the Northern region and of TAVI in the Lisbon region.

The present study showed an increase in the number of hospitalisations with procedures for AS from 2015 to 2017. This uprising was more expressive for TAVI, contrasting with a decreased in SAVR. The upward trend in TAVI, found in this study, is in accordance with a worldwide trend.[10 12] This result may characterise a substitution effect in the use of technologies.[10]

Although TAVI showed an increasing trend, its spatial distribution was not uniform across the Portuguese territory, as there was a concentration of TAVI among patients living in the Lisbon region. At the same time, the SAVR procedure was concentrated among patients living in the northern region of Portugal. It is crucial to understand whether this spatial variability would result in disparities on access to health technology.[14] This could be an important public health issue since inequalities on access to technologies can exacerbate health inequities.

Adequate access to healthcare can promote better levels of health.[27 28] This requires a comprehensive, timely and high-quality health system coverage (adequate healthcare services, screening, diagnosis and treatment) to improve the population's health status.[27] This study revealed significant differences in the geographical distribution of AS procedures according to the patients' residence, even when adjusted for its individual characteristics. This could suggest the existence of health disparities, which may worsen health inequalities.

This geographical variability may be associated with a concentration of medical expertise regarding the type of procedures. According to the available evidence, regional differences in service provision may be associated with heterogeneous professional training and technical specialisation. Furthermore, financial incentives, as well as population preferences to be treated in a particular region, might also contribute to regional

Table 1 Study population characteristics by SAVR and TAVI in Portuguese National Health Service hospitals admissions database from 2015 to 2017.

Characteristics			SAVR n=7433	TAVI n=965	Total	P value (SAVR vs TAVI)
Sex	Male	n (%)	4226 (56.9)	430 (44.6)	4656 (55.4)	**<0.001**
Age	Years	Mean (SD)	70 (11)	81 (7)	8398 (100.0)	**<0.001**
Year of hospitalisation	2015	n (%)	2530 (34.0)	192 (19.9)	2722 (32.4)	**<0.001**
	2016	n (%)	2503 (33.7)	329 (34.1)	2832 (33.7)	
	2017	n (%)	2400 (32.3)	444 (46.0)	2844 (33.9)	
Type of admission	Elective	n (%)	6737 (90.6)	829 (85.9)	7566 (90.1)	**<0.001**
	Non-elective	n (%)	696 (9.4)	136 (13.1)	832 (9.9)	
Country region	Norte	n (%)	2862 (41.2)	246 (25.7)	3108 (39.4)	**<0.001**
	Centro	n (%)	1373 (19.8)	154 (16.1)	1527 (19.3)	
	LVT	n (%)	1835 (26.4)	443 (46.3)	2278 (28.8)	
	Alentejo	n (%)	467 (6.7)	71 (7.4)	538 (6.8)	
	Algarve	n (%)	259 (3.7)	31 (3.2)	290 (3.7)	
	AR (Azores and Madeira)	n (%)	146 (2.1)	11 (1.2)	157 (2.0)	
Length of stay	Days	Mean (SD)	13 (15)	13 (14)	8398 (100.0)	0.602
Type of patient	NHS	n (%)	7286 (98.0)	954 (98.9)	8240 (98.1)	0.077
	No NHS	n (%)	147 (2.0)	11 (1.1)	158 (1.9)	
Destination after discharge	Home	n (%)	6605 (88.9)	841 (87.2)	7446 (88.7)	0.058
	Death	n (%)	284 (3.8)	33 (3.4)	317 (3.8)	
	Others*	n (%)	544 (7.3)	91 (9.4)	635 (7.5)	
Severity	Minor	n (%)	2365 (31.8)	268 (27.8)	2633 (31.3)	**<0.001**
	Moderate	n (%)	3941 (53.0)	459 (47.6)	4400 (52.4)	
	Major	n (%)	893 (12.0)	213 (22.1)	1106 (13.2)	
	Extreme	n (%)	234 (3.1)	25 (2.6)	259 (3.1)	
CCI	Index	Mean (SD)	1.33 (1.34)	1.80 (1.68)	8398 (100.0)	**<0.001**
CCI	0–2	n (%)	6231 (83.8)	674 (69.8)	6905 (82.2)	**<0.001**
	≥ 3	n (%)	1202 (16.2)	291 (30.2)	1493 (17.8)	
Myocardial infarction	Yes	n (%)	466 (6.3)	102 (10.6)	568 (6.8)	**<0.001**
Congestive heart failure	Yes	n (%)	2568 (34.5)	366 (37.9)	2934 (34.9)	**0.041**
Peripheral vascular disease	Yes	n (%)	1507 (20.3)	120 (12.4)	1627 (19.4)	**<0.001**
Cerebrovascular disease	Yes	n (%)	490 (6.6)	110 (11.4)	600 (7.1)	**<0.001**
Dementia	Yes	n (%)	21 (0.3)	4 (0.4)	25 (0.3)	0.522†
Chronic pulmonary disease	Yes	n (%)	764 (10.3)	139 (14.4)	903 (10.7)	**<0.001**
Connective tissue disease	Yes	n (%)	87 (1.2)	19 (2.0)	106 (1.3)	**0.045**
Peptic ulcer disease	Yes	n (%)	15 (0.2)	3 (0.3)	18 (0.2)	0.453†
Mild liver disease	Yes	n (%)	109 (1.5)	22 (2.3)	131 (1.5)	0.071
Diabetes without chronic complication	Yes	n (%)	1779 (23.9)	208 (21.6)	1987 (23.7)	0.107
Diabetes with chronic complication	Yes	n (%)	202 (2.7)	47 (4.9)	249 (3.0)	**<0.001**

Continued

Table 1 Continued

Characteristics			SAVR n=7433	TAVI n=965	Total	P value (SAVR vs TAVI)
Hemiplegia or paraplegia	Yes	n (%)	78 (1.0)	9 (0.9)	87 (1.0)	0.866
Renal disease	Yes	n (%)	647 (8.7)	225 (23.3)	872 (10.4)	**<0.001**
Any malignancy, including lymphoma and leukaemia, except malignant neoplasm of skin	Yes	n (%)	64 (0.9)	28 (2.9)	92 (1.1)	**<0.001**
Moderate or severe liver disease	Yes	n (%)	8 (0.1)	0 (0.0)	8 (0.1)	0.609†
Metastatic solid tumour	Yes	n (%)	9 (0.1)	4 (0.4)	13 (0.2)	0.053†
AIDS/HIV	Yes	n (%)	8 (0.1)	1 (0.1)	9 (0.1)	1.000†

P-values lower than 0.05 were highlighted in bold.
*Another institution with inpatient care, home care, medical counter opinion, specialised care (tertiary), palliative care, posthospital care, long-term medical care.
†Fisher's exact test.
AR, autonomous regions; CCI, Charlson Comorbidity Index; LVT, Lisbon area; NHS, National Health Service; SAVR, surgical aortic valve replacement; TAVI, transcatheter aortic valve implantation.

differences in healthcare utilisation.[27 28] The variability in the geographic distribution may be a result of technological incorporation. Technology can be incorporated progressively across the country, at a various regional place. Delays in providing specific procedures or treatments can deteriorate patients health status, decrease their quality of life and/or worsen disease severity.[29] This might contribute to escalation of consumption of health resources in the future, and potentially increasing health system expenditures.[14 30]

This study showed that TAVI was more frequent in older patients, that is, 80 years old. Other studies have also demonstrated a positive association with age.[31] In the review conducted by Osnabrugge *et al*,[1] patients over 75 years of age were more likely to be at more severe stages of the AS disease due to late diagnosis. Thus, TAVI was commonly the only possible approach due to their clinical frailty.

Additionally, higher CCI values were associated with an increased chance of TAVI, suggesting that it is used for more frail individuals. In contrast, many patients with lower CCI classification have undergone in SAVR. These results are consistent with the literature,[19 20 22 32 33] which suggests that TAVI is usually performed more often in patients with grater frailty.

In summary, the results showed that older age and higher CCI were relevant explanatory factors of TAVI utilisation, which is consistent with international guidelines[34] and the Portuguese consensus,[5] which state that TAVI is indicated for the treatment of patients at increased surgical risk.[11 20] TAVI is a less invasive procedure, recommended for inoperable patients not eligible for SAVR.[11 34] This could explain why TAVI patients had a higher percentage of admission from non-elective services, comparing with SAVR, as TAVI does not require an open-heart surgery.[12 34]

All studies have limitations, and this study is no exception. This is a secondary database, so the data was not intended for academic research. We cannot infer causality with the present study design and data. Therefore, the results should be interpreted as associations between the variables. Finally, the CCI is represented by a specific group of comorbidities commonly used in observational studies.[19 20 22 32] Other important comorbidities might influence AS severity and medical decision on therapeutic choice might not be considered.

Implications for practice and future research

The findings of this study have important implications. It was identified that increasing age and a higher CCI were associated with TAVI. Additionally, asymmetries in the spatial distribution of AS treatment might impact the access to healthcare services and technologies.

Future studies should update the existing evidence by extending the time horizon and using a longitudinal design. Also, research can focus on other AS-specific indicators, such as the Society of Thoracic Surgeons risk index, the New York Heart Association functional classification or the European System for Cardiac Operative risk assessment. Future studies could also focus on other therapeutic alternatives, such as therapeutic management without surgical intervention.

The place of residence should not be the most relevant determinant of treatment pattern. A more in-depth analysis is needed to understand if AS treatment is being performed according to appropriate referral criteria and if freedom of choice of treatment location is being guaranteed to the patients.

Table 2 Results for the logistic regression models for the likelihood of TAVI use, in the Portuguese NHS, from 2015 to 2017.

Characteristics		Unadjusted		Adjusted	
		OR (95% CI)	P value	OR (95% CI)	P value
Sex	Male	Reference		Reference	
	Female	1.64 (1.43 to 1.88)	**<0.001**	1.17 (0.10 to 1.37)	0.053
Age (per 1 unit increase)	Years	1.22 (1.21 to 1.24)	**<0.001**	1.21 (1.20 to 1.23)	**<0.001**
Year of hospitalisation	2015	Reference		Reference	
	2016	1.73 (1.44 to 2.09)	**<0.001**	1.68 (1.37 to 2.07)	**<0.001**
	2017	2.44 (2.04 to 2.91)	**<0.001**	2.87 (2.34 to 3.52)	**<0.001**
Type of admission	Elective	Reference		Reference	
	Non-elective	1.59 (1.30 to 1.94)	**<0.001**	1.18 (0.92 to 1.50)	0.191
Country region	Norte	Reference		Reference	
	Centro	1.31 (1.06 to 1.61)	**0.014**	1.64 (1.29 to 2.08)	**<0.001**
	Lisbon	2.81 (2.38 to 3.32)	**<0.001**	2.62 (2.16 to 3.18)	**<0.001**
	Alentejo	1.77 (1.34 to 2.34)	**<0.001**	1.84 (1.34 to 2.53)	**<0.001**
	Algarve	1.39 (0.94 to 2.07)	0.100	1.44 (0.93 to 2.24)	0.101
	Azores and Madeira*	0.88 (0.47 to 1.64)	0.680	1.21 (0.61 to 2.41)	0.582
Type of patient	NHS	Reference		–	
	No NHS	1.75 (0.95 to 3.24)	0.075		
Severity	Minor	Reference		–	
	Moderate	1.03 (0.88 to 1.21)	0.736		
	Major	2.11 (1.73 to 2.56)	**<0.001**		
	Extreme	0.94 (0.61 to 1.45)	0.789		
Charlson Comorbidity Index	Index	1.24 (1.18 to 1.29)	**<0.001**	–	
Charlson Comorbidity Index	0–2	Reference		Reference	
	≥ 3	2.24 (1.93 to 2.60)	**<0.001**	2.55 (2.10 to 3.10)	**<0.001**

P-values lower than 0.05 were highlighted in bold.
*Autonomous Regions of Azores and Madeira.
NHS, National Health Service.

Health policies should aim to reduce barriers to health-care access while promoting access to technologies at all levels of care. This goal can be achieved by training and updating health professionals' knowledge and skills, and if needed, providing incentives for innovative health technologies adoption.

CONCLUSIONS

The TAVI procedure changed the management of AS worldwide. Two decades ago, it emerged as a solution for individuals not eligible for SAVR, since it was a less invasive procedure. According to this study, older age and higher CCI were significant explanatory factors of TAVI utilisation in the Portuguese NHS hospitals, from 2015 to 2017. This is consistent with the literature, and with national and international guidelines. Additionally, it was observed geographic differences in the use of TAVI that did not seem to be explained by patients' individual characteristics. This should be further investigated since this access variability might contribute to worsening health inequalities.

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REFERENCES

1 Osnabrugge RLJ, Mylotte D, Head SJ, *et al*. Aortic stenosis in the elderly. *Journal of the American College of Cardiology* 2013;62:1002–12.
2 Tarride JE, Luong T, Goodall G, *et al*. A Canadian cost-effectiveness analysis of SAPIEN 3 transcatheter aortic valve implantation compared with surgery, in intermediate and high-risk severe aortic stenosis patients. *Clinicoecon Outcomes Res* 2019;11:477–86.
3 Gavina C. Epidemiology of valvular heart disease in Portugal: the time has come for the heart valve unit. *Rev Port Cardiol (Engl Ed)* 2018;37:S0870-2551(18)30790-X:999–1000.:.
4 Gialama F, Prezerakos P, Apostolopoulos V, *et al*. Systematic review of the cost-effectiveness of transcatheter interventions for valvular heart disease. *Eur Heart J Qual Care Clin Outcomes* 2018;4:81–90.
5 Campante Teles R, Gama Ribeiro V, Patrício L, *et al*. Posição de consenso sobre válvulas aórticas percutâneas transcatéter em Portugal. *Revista Portuguesa de Cardiologia* 2013;32:801–5.
6 Généreux P, Stone GW, O'Gara PT, *et al*. Natural history, diagnostic approaches, and therapeutic strategies for patients with asymptomatic severe aortic stenosis. *J Am Coll Cardiol* 2016;67:S0735-1097(16)01028-7:2263–88.:.
7 Kang D-H, Park S-J, Lee S-A, *et al*. Early surgery or conservative care for asymptomatic aortic stenosis. *N Engl J Med* 2020;382:111–9.
8 Bakaeen FG, Rosengart TK, Carabello BA. Aortic stenosis. *Ann Intern Med* 2017;166:ITC1–16.
9 Lester SJ, Heilbron B, Gin K, *et al*. The natural history and rate of progression of aortic stenosis. *Chest* 1998;113:1109–14.
10 Pilgrim T, Windecker S. Expansion of transcatheter aortic valve implantation: new indications and socio-economic considerations. *Eur Heart J* 2018;39:2643–5.
11 Leon MB, Smith CR, Mack M, *et al*. Transcatheter aortic-valve implantation for aortic stenosis in patients who can not undergo surgery. *N Engl J Med* 2010;363:1597–607.
12 Guerreiro C, Ferreira PC, Teles RC, *et al*. Short and long-term clinical impact of transcatheter aortic valve implantation in Portugal according to different access routes: data from the Portuguese national Registry of TAVI. *Rev Port Cardiol (Engl Ed)* 2020;39:S0870-2551(20)30436-4:705–17.:.
13 Durko AP, Osnabrugge RL, Kappetein AP. Long-Term outlook for transcatheter aortic valve replacement. *Trends Cardiovasc Med* 2018;28:S1050-1738(17)30121-4:174–83.:.
14 Timmermans S, Kaufman R. Technologies and health inequities. *Annu Rev Sociol* 2020;46:583–602. 10.1146/annurev-soc-121919-054802 Available: https://www.annualreviews.org/toc/soc/46/1
15 Carnero-Alcázar M, Maroto-Castellanos LC, Hernández-Vaquero D, *et al*. Isolated aortic valve replacement in Spain: national trends in risks, valve types, and mortality from 1998 to 2017. *Rev Esp Cardiol (Engl Ed)* 2021;74:S1885-5857(20)30262-0:700–7.:.
16 Quan H, Sundararajan V, Halfon P, *et al*. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Med Care* 2005;43:1130–9.
17 Charlson ME, Pompei P, Ales KL, *et al*. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987;40:373–83.
18 Charlson ME, Carrozzino D, Guidi J, *et al*. Charlson comorbidity index: a critical review of Clinimetric properties. *Psychother Psychosom* 2022;91:8–35.
19 Bagur R, Martin GP, Nombela-Franco L, *et al*. Association of comorbid burden with clinical outcomes after transcatheter aortic valve implantation. *Heart* 2018;104:2058–66.
20 Bouleti C, Himbert D, Iung B, *et al*. Long-Term outcome after transcatheter aortic valve implantation. *Heart* 2015;101:936–42.
21 Pylväläinen J, Talala K, Murtola T, *et al*. Charlson comorbidity index based on hospital episode statistics performs adequately in predicting mortality, but its discriminative ability diminishes over time. *Clin Epidemiol* 2019;11:923–32.
22 Dautzenberg L, Pals JEM, Lefeber GJ, *et al*. Predictors of clinical outcome following transcatheter aortic valve implantation: a prospective cohort study. *Open Heart* 2021;8:e001766.
23 Naing NN. Easy way to learn standardization: direct and indirect methods. *Malays J Med Sci* 2000;7:10–5.
24 QGIS. Development Team. QGIS geographic information system. open source geospatial foundation project. 2022. Available: https://www.qgis.org/en/site/ [Accessed 26 Jul 2022].
25 AMA - Agência para a Modernização Administrativa, I. P. Distritos de Portugal. 2021. Available: https://dados.gov.pt/en/datasets/distritos-de-portugal/
26 INE. Instituto nacional de estatística [Internet]. 2022. Available: https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&indOcorrCod=0004163&xlang=pt&contexto=bd&selTab=tab2
27 Andersen RM, Davidson PL, Baumeister SE. IMPROVING ACCESS TO CARE. In: *Changing the US Health Care System: Key Issues in Health Services Policy and Management*. 4th Edition. Jossey-Bass, 2014: 33–69.
28 Babitsch B, Gohl D, von Lengerke T. Re-revisiting Andersen's behavioral model of health services use: a systematic review of studies from 1998-2011. *Psychosoc Med* 2012;9:Doc11.
29 Lakdawalla DN, Phelps CE. Health technology assessment with risk aversion in health. *J Health Econ* 2020;72:S0167-6296(19)30920-8:102346.:.
30 Skedgel C, Henderson N, Towse A, *et al*. Considering severity in health technology assessment: can we do better? *Value Health* 2022;25:S1098-3015(22)00105-X:1399–403.:. 10.1016/j.jval.2022.02.004 Available: https://www.sciencedirect.com/science/article/pii/S109830152200105X
31 Wenaweser P, Pilgrim T, Kadner A, *et al*. Clinical outcomes of patients with severe aortic stenosis at increased surgical risk according to treatment modality. *J Am Coll Cardiol* 2011;58:2151–62.
32 George S, Kwok CS, Martin GP, *et al*. The influence of the Charlson comorbidity index on procedural characteristics, VARC-2 endpoints and 30-day mortality among patients who undergo transcatheter aortic valve implantation. *Heart Lung Circ* 2019;28:S1443-9506(18)31989-9:1827–34.:.
33 Mendez-Bailon M, Lorenzo-Villalba N, Muñoz-Rivas N, *et al*. Transcatheter aortic valve implantation and surgical aortic valve replacement among hospitalized patients with and without type 2 diabetes mellitus in Spain (2014-2015). *Cardiovasc Diabetol* 2017;16:144.
34 Vahanian A, Beyersdorf F, Praz F, *et al*. 2021 ESC/EACTS guidelines for the management of valvular heart disease: developed by the task force for the management of valvular heart disease of the European Society of cardiology (ESC) and the European association for cardio-thoracic surgery (EACTS). *Rev Esp Cardiol (Engl Ed)* 2022;75:S1885-5857(22)00112-8:524.:.