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Percutaneous Coronary Intervention in Specialized Hospitals and General Hospitals: An Empirical Analysis for Brazil

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Abstract: This paper analyzes how undergoing percutaneous coronary intervention in specialized hospital impacts health outcomes for patients. Data are from the Hospital Information System and the National Registry of Health Centers of the Brazilian Unified Health System. We use the model of instrumental variables, in which the geographic distribution of patients and hospitals is explored as a source of exogenous variation for the endogenous variables. Results indicate that treatment in a specialized hospital has a positive impact on patients' health.

Keywords: Specialized Hospital, Instrumental Variables, Mortality, Healthcare Market

JEL Classification Number: I11 I12

1. Introduction

Brazil has been undergoing a process of demographic transition, in which the proportion of people aged 60 and over doubled between 1970 and 2000 (Paim et al., 2011). The elderly population is expected to outnumber the population of children and adolescents in 2050 in over 38 million individuals (Brasil, 2010). This change in the age structure of the Brazilian population changed morbidity and mortality patterns in the country. In 2007, over 70% of deaths in Brazil were associated with Chronic Noncommunicable Diseases (NCDs) - including cardiovascular disease - while mortality from infectious and parasitic diseases was 10% (Schmidt et al., 2011). This situation contrasts the numbers observed in 1930, when 45.6% of deaths in Brazilian capital cities were associated with infectious diseases (Brasil, 2009).

Regarding cardiovascular diseases, despite the decrease in lethality, they are the main cause of death in the country and those that most burden the Brazilian health system (Schmidt et al., 2011). The Brazilian hospital system has specialized treatment centers in pediatrics, cardiology, orthopedics, oncology, maternity and psychiatry, which must have appropriate technological and human resources to provide clinical and surgical urgent and emergency care in those areas. In this sense, given this new Brazilian demographic pattern, centers specializing in heart disease, above all, may play a relevant role in the healthcare market in Brazil, if we consider that these centers offer better quality services, due to their specialization and the potential gains of scale that come from it (Clark and Huckman, 2012; Greenwald et al., 2006; Nallamothu et al., 2007).

Several studies have sought to find whether patients treated in specialized hospitals have better health outcomes than patients receiving treatment in general hospitals (Barker et al., 2011; Barro et al., 2006; Clark and Huckman, 2012; Cram et al., 2005; Greenwald et al., 2006; Hwang et al., 2007; Nallamothu et al., 2007; Sanwald and Schober, 2017; Young et al., 2005). The research focuses primarily on cardiology and traumatology. Part of those studies focuses on the healthcare market of the United States of America, which has experienced a substantial increase in the number of specialized hospitals. The subject has not been addressed in Brazil: through a literature search, we found only one study (Ramos et al., 2015) that seeks to determine whether patients treated in specialized hospitals have better health outcomes. The study, however, does an aggregate analysis and does not stick to a specific procedure, and also does not use appropriate methodology to identify a causal relation.

Thus, it seems appropriate to address the issue, especially regarding hospitals specializing in heart disease. Evidence that show whether the outcomes of patients treated in specialized cardiology units are better (or worse) than those observed for patients treated in general hospitals can contribute greatly to the formulation of public policies aimed at improving the quality of care provided by Brazilian hospitals.

Therefore, the aim of this paper is to evaluate the impact on probability of death of patients having undergone Percutaneous Coronary Intervention (PCI) in a specialized hospital. This study presents at least two important contributions to the investigation of cardiovascular diseases in Brazil. First, it is one of the first to analyze the theme "*specialized hospital versus general hospital*" in Brazilian hospital services. Second, it will use econometric technique that will make it possible to control unobserved factors that may affect the patient's probability of death, such as unobserved heterogeneity among patients treated in specialized hospitals and general hospitals.

In section 2 we present data used and empirical strategy employed. Section 3 presents results and section 4 provides final comments.

2. Methodology

2.1. Data

The data are from the Hospital Information System (*Sistema de InformaçõesHospitalares* - SIH) of the Brazilian Unified Health System (*Sistema Único de Saúde* - SUS) and from the National Registry of Health Centers (*Cadastro Nacional de Estabelecimentos de Saúde* - CNES) for the period 2008-2014. The studied procedure is Percutaneous Coronary Intervention (PCI). PCI consists of non-surgical treatment of blocked coronary arteries. During the procedure, a balloon catheter is inserted into the obstructed artery in order to increase blood flow to the heart. After the artery is cleared, it is possible to implant an endovascular prosthesis, called a stent. The Brazilian Society of Cardiology (Mattos et al., 2008) indicates the procedure for clinical cases of stable and unstable angina, silent myocardial ischemia, and acute myocardial infarction.

In SIH-SUS there are 429,493 records of PCIs. 18,516 cases of permanence, 9,444 records of transfer, and 3,378 records of administrative closure were excluded. We also excluded patients treated in hospitals with less than 10 PCIs over the year (n = 188), 16,415 patients with invalid ZIP code and 10 patients with no information on GDP per capita. The final sample consisted of 381,542 patients undergoing PCI, of which 302,384 were performed in 205 general hospitals and 79,158 in 25 specialized hospitals. Some descriptive statistics of specialized and general hospitals are shown in Table 1.

Table 1: Characteristics of Specialized and General Hospitals (2008 - 2014)

Variable	Specialized hospital (n=25)	General hospital (n=205)	*P*
Patient characteristics			
Age, years, mean (SD)	62,60 (11,24)	62,54 (10,96)	0.1673
Woman, n (%)	28,353 (35.82)	107,727 (35.63)	0.3145
Urgency, n (%)	45,170 (57.06)	190,323 (62.91)	<0,001
AMI[a], n (%)	24,850 (31.39)	75,860 (25.09)	<0,001
ICU days, mean (SD)	1,07 (2,71)	0,99 (2,21)	<0,001
Hospital characteristics			
Volume, mean (SD)	1033 (598)	513 (487)	<0,001
Treated patients, mean (SD)	5.619 (3986)	11,807 (8829)	<0,001
Permanence, mean (SD)	7,76 (3,16)	5.76 (1.76)	<0,001
Beds, mean (SD)	219 (152)	370 (295)	<0,001
In-hospital mortality, n (%)	2,219 (2.80)	7,834 (2.59)	<0,001

Notes:[a] Acute Myocardial Infarction. Source: Compiled with data from the Brazilian Ministry of Health (2015).

2.2. Empirical strategy

The empirical strategy is based on a model in which the dependent variable y_{ihmt} is a binary variable that indicates whether patient *i*, hospitalized in hospital h, living in city *m*, in the year *t*, died or not, after undergoing PCI. Thus, the following model will be estimated, using Ordinary Least Squares (OLS):

$$y_{ihmt} = \beta_0 + \beta_1 esp_{ihmt} + \beta_2 ln(vol)_{hmt} + x'_{ihmt}\beta_3 + f'_{hmt}\beta_4 + m'_{mt}\beta_5 + year'_t\beta_6 + \varepsilon_{ihmt} \quad (1)$$

where esp_{ihmt} indicates whether patient *i*, admitted to hospital h, living in city *m*, in the year t, has undergone PCI at a hospital specialized in heart disease, $ln(vol)_{hmt}$ is the log of hospital volume in the year *t*, x'_{ihmt} are patient characteristics (age, sex, urgency, diagnosis, ICU days and Charlson index (Charlson et al., 1987)), f'_{hmt} are hospital characteristics (beds, teaching activity, patients treated, mean permanence, State), m'_{mt} are characteristics of the city where the individual i lives (*ln* GDP per capita, physicians and cardiologists per thousand inhabitants) and $year'_t$ are year dummies.

The option for Linear Probability Model (LPM), instead of nonlinear models such as probit and logit, was due to the fact that LPM is more flexible for our case, in which we have two endogenous variables, as we will see next. In addition, LPM makes it possible to deal with heteroscedasticity more directly. If we estimate the model as presented in (1), we neglect the endogeneity of two variables: specialized hospital and volume. Endogeneity may be the result of reverse causality, omitted-variable bias or measurement error. The first is related to the fact that the explanatory variable affects the response variable, but is also affected by it. The second happens when some factor influencing the outcome is omitted and correlated with some covariate. The third occurs when some covariate is measured with error.

The specialized hospital variable is endogenous because although it is possible to control some patient characteristics, it is not possible to control unobserved factors, especially lifestyle and health status, that affect the probability of death. If there are unobserved characteristics that lead to the non-random distribution of patients between general and specialized hospitals, a source of exogenous variation is needed to assess the impact of receiving treatment at a specialized hospital. The identification strategy used to evaluate the impact of this variable is similar to that of Franceset al. (2000) and Sanwald e Schober (2017). We will use the differential distance, which corresponds to the distance between the patient's residence and the nearest specialized hospital minus the distance between the patient's residence and the nearest general hospital. In mathematical terms:

$$D_{ihmt} = Dist_{ie} - Dist_{ig} \quad (2)$$

where $Dist_{ie}$ is the distance between the residence of patient $i$and the nearest specialized hospital e; and $Dist_{ig}$ is the distance between the residence of patient $i$and the nearest general hospital g. The hypothesis, as observed Frances et al.(2000), is that the location of the patient's residence independently predicts the probability of being treated in a specialized hospital. The smaller the D_{ihmt}, the closer patient i will be to a specialized unit and the greater the likelihood that he will receive treatment in this unit. This variable will be used as an instrument for the specialized hospital variable.

Volume is also endogenous in (1), mainly due to the reverse causality between mortality and volume. This is the selective referral hypothesis discussed in the literature, according to which hospitals with better results (lower mortality rates) attract more patients, that is, the higher quality of hospitals increases their volume. Thus, the instrument for volume is the expected volume, similar to that used by Barkeret al. (2011), based on the distance between the patients' residence and the hospitals. In mathematical terms:

$$VE_h = \sum_{i=1}^{P} \frac{1/d_{ih}^2}{\sum_{h=1}^{H}(1/d_{ih}^2)} \quad (3)$$

where P is the number of patients, H is the number of hospitals and d_{ih}^2 is the square of the distance between the residence of patient i and hospital h. Thus, we estimate two first stage equations as follows:

$$\begin{aligned} esp_{ihmt} &= \alpha_0 + \alpha_1 D_{ihmt} + \alpha_2 VE_{ht} + x'_{ihmt}\alpha_3 + f'_{hmt}\alpha_4 \\ &\quad + m'_{mt}\alpha_5 + year'_t\alpha_6 + \nu_{ihmt} \end{aligned} \quad (4)$$

$$\begin{aligned} ln(vol)_{ihmt} &= \gamma_0 + \gamma_1 D_{ihmt} + \gamma_2 VE_{ht} + x'_{ihmt}\gamma_3 + f'_{hmt}\gamma_4 \\ &\quad + m'_{mt}\gamma_5 + year'_t\gamma_6 + \upsilon_{ihmt} \end{aligned} \quad (5)$$

By estimating these two equations, we will obtain $\widehat{esp_{ihmt}}$ and $\widehat{ln(vol)}_{ihmt}$, that is, the estimated values for the two endogenous variables. In the second stage, then, we enter these estimated variables where the endogenous variables were, that is, we estimate the following equation:

$$y_{ihmt} = \delta_0 + \delta_1 \widehat{esp_{ihmt}} + \delta_2 \widehat{ln(vol)}_{ihmt} + x'_{ihmt}\delta_3 + f'_{hmt}\delta_4 + m'_{mt}\delta_5 + year'_t\delta_6 + \xi_{ihmt} \quad (6)$$

The coefficient of interest in this case is δ_1, which will tell us what is the impact on the probability of the individual dying, since he has undergone PCI in a specialized hospital, controlling for observed and unobserved factors that may affect such probability.

3. Results

In table 2 we present the coefficients obtained by OLS for the variable that indicates whether the patient has undergone PCI in a specialized hospital and for the volume log. Columns (1) to (5) present different models and the last four rows in the table indicate which controls are being included in the estimates. In models (1) and (2) the specialized hospital variable is not statistically significant. Including the hospital controls makes the coefficient significant (Model 3), showing that not controlling such characteristics overestimates the relationship between specialized hospital and probability of death. Model 4 presents results identical to Model 3. The magnitude of the specialized hospital coefficient increases in Model 5, with the inclusion of volume.

Table 2: Effect of specialized hospital treatment on the probability of death (Ordinary Least Squares)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5
Specialized hospital	0.0021	0.0003	-0.0080**	-0.0080***	-0.0108***
	(0.0059)	(0.0043)	(0.0035)	(0.0035)	(0.0039)
Volume (In)					0.0025*
					(0.0013)
Observations	381,542	381,542	381,542	381,542	381,542
R2	0.0001	0.0645	0.0663	0.0663	0.0664
Year FS	YES	YES	YES	YES	YES
Patient Controls	NO	YES	YES	YES	YES
Hospital Controls	NO	NO	YES	YES	YES
City Controls	NO	NO	NO	YES	YES

Notes: Cluster-robust standard errors at the hospital level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. **Source:** compiled with data from the Brazilian Ministry of Health (2015).

Although some studies in the USA have shown that treatment in a specialized hospital reduces the chance of negative outcomes (Clark and Huckman, 2012; Greenwald et al., 2006; Nallamothu et al., 2007), most of the findings go in the opposite direction and do not indicate an advantage in relation to the specialized hospital (Barker et al., 2011; Barro et al., 2006; Cram et al., 2005; Hwang et al., 2007; Young et al., 2005). The effect of specialized hospital treatment disappears in these when volume is controlled, suggesting that the observed relationship is due to the fact that specialized hospitals treat more patients than general hospitals. In Brazil, the inclusion of procedures volume as control causes the effect of the specialized hospital on the outcome to be greater. Sanwald e Schober (2017), in turn, using the instrumental variables method, show for Austria that the probability of death is significantly smaller when the patient is treated in a specialized hospital.

The possible endogeneity of the specialized hospital variable and the volume may be biasing the results in table 2. Table 3 presents the results for the instrumental variables model. The first stage results show that the instruments are significantly correlated with the endogenous variables. The second stage results in (2) indicate that the specialized hospital variable is significant at 10%.

Table 3: Effect of specialized hospital treatment on the probability of death (Instrumental Variables)

	(1)		(2)	
Variables	**Endogenous volume**	**Cluster-robust standard errors**	**Volume and specialized endogenous**	**Cluster-robust standard errors**
Volume (In)	0.0077**	(0.0039)	0.0085**	(0.0041)
Specialized hospital	-0.0165***	(0.0055)	-0.0220*	(0.0122)
First stage (Volume)				
Expected Volume	0.0015***	(0.00005)	0.0017***	(0.00005)
Differential distance	-		-0.0003***	(0.00005)
First stage (Specialized)				
Expected Volume	-		0.0002***	(0.00002)
Differential distance	-		-0.0006***	(0.00002)
Observations	381,542		381,542	
R^2	0.0660		0.0658	
F Statistic of the first stage (Volume)	2113.54***		1455.04***	
F Statistic of the first stage (Specialized)	-		1732.82***	
Year FS	YES		YES	
Patient Controls	YES		YES	
Hospital Controls	YES		YES	
City Controls	YES		YES	

Note: Cluster-robust standard errors *** p<0.01, ** p<0.05, * p<0.1. **Source:** compiled with data from the Brazilian Ministry of Health (2015).

OLS results indicate that treatment at a specialized hospital reduces the probability of death by 1.08 percentage points (pp). The IV results, in turn, are 1.65 pp in (1) and 2.2 pp in (2), indicating that the direction of bias caused by endogeneity is negative, that is, the OLS estimates underestimate the treatment effect in a specialized hospital.

4. Conclusions

This paper investigates whether the outcomes of patients treated in specialized hospitals are better than those of patients treated in general hospitals. We use data from 2008 to 2014 of the Hospital Information System and the National Register of Health Centers. The model of instrumental variables is used because of the endogeneity of the variable that indicates specialized hospital and because of the volume, in which the geographic distribution of patients and hospitals as a source of exogenous variation is explored.

Results show that specialized hospitals treat more patients in critical conditions than general hospitals. The estimated models show that the outcomes of patients treated in specialized hospitals are better than those of patients treated in general hospitals. Incentives to enable more hospitals to become specialized would tend to improve patient outcomes. This incentive already exists, as specialized hospitals receive more resources than general hospitals. In the future, it could be investigated how this greater availability of resources is an incentive for hospitals to become specialized, and to verify the cost-benefit of having more specialized hospitals.

Among the limitations of this work, the following stand out: 1) the use of administrative data rather than clinical data, which would provide much more detailed information on the patient's health status; 2) the fact that our unit of observation is the hospitalization and not the patient, which can be considered more than once; and 3) the creation of the instruments only takes into account the geographical distance between the patients' residence and the hospitals, so it would be better to consider the transport infrastructure and the ease of access to the hospitals.

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