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ORIGINAL ARTICLE

The impact of the institutional abdominoperineal resections volume on short-term outcomes and expenses: a nationwide study

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Abstract

Background The aim of this study was to evaluate the influence of the institutional volume of abdominoperineal resections (APR) on the short-term outcomes and costs in the Brazilian Public Health system.

Methods This population-based study evaluated the number of APRs by institutions performed in the Brazilian Public Health system from January/2010 to July/2022. Data were extracted from a public domain from the Brazilian Public Health system.

Results Four hundred and twelve hospitals performed APRs and were included. Only 23 performed at least 5 APRs per year on average and were considered high-volume institutions. The linear regression model showed that the number of hospital admissions for APRs was negatively associated with in-hospital mortality (Coef. = − 0.001; $p = 0.013$) and length of stay in the intensive care unit (Coef. = − 0.006; $p = 0.01$). The number of hospital admissions was not significantly associated with personnel, hospital, and total costs. The in-hospital mortality in high-volume institutions was significantly lower than in low-volume institutions (2.5 vs. 5.9%; $p: < 0.001$). The mean length of stay in the intensive care unit was shorter in high-volume institutions (1.23 vs. 1.79 days; $p = 0.021$). In high-volume institutions, the personnel (R$ 952.23 [US$ 186.64] vs. R$ 11,129.04 [US$ 221.29]; $p = 0.305$), hospital (R$ 4078.39 [US$ 799.36] vs. R$ 4987.39 [US$ 977.53]; $p = 0.111$), and total costs (R$ 5030.63 [US$ 986.00] vs. R$ 6116.71 [US$ 1198.88]; $p = 0.226$) were lower.

Conclusions Higher institutional APR volume is associated with lower in-hospital mortality and less demand for intensive care. The findings of this nationwide study may affect how Public Health manages APR care.

Keywords Colorectal neoplasms · Colorectal surgery · Abdominoperineal resection · Colon; Public health

Introduction

Colorectal cancer is the third-most common cancer and are the second cancer-related cause of death worldwide, with an incidence rate of 1.9 million new cases and 0.9 million deaths in 2020 [1]. In Brazil, the fifth-most populous country in the world, the number of colon malignancy-related deaths was over 29,000 in 2019 [2]. The incidence of colorectal cancer has been increasing in the last decades, mainly in middle- and low-income countries [1]. Moreover, the incidence of early onset rectal cancer has steadily increased in some countries [3].

Rectal cancer resection imposes a great technical difficulty due to the proximity of pelvic organs, including the urinary tract, reproductive organs, and neural and vascular structures. The proximity to the pelvic floor often necessitates an abdominoperineal resection (APR). Some of the most common postoperative complications are inadvertent lesions to these organs, abscesses, wound-healing complications, and perineal dehiscence [4, 5]. One quarter of the patients who have APR may experience intraoperative complications, with 5% intra-hospital mortality [4].

There is usually significant heterogeneity of high-complexity surgery outcomes among surgeons and institutions [6, 7]. Understanding the reasons for this variability and searching for the factors associated with better surgical outcomes is essential for policymakers and rectal amputation

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insurance companies. Health systems are interested in finding the perfect programs to achieve satisfactory outcomes of APR with the lowest use of hospital and human resources.

The Brazilian Public Health system (Unified Health System, SUS) is the largest Public Health system in the world, covering about 200 million people [8, 9]. Free access to healthcare is guaranteed by law in Brazil. However, due to the substantial healthcare costs, the management of APRs in the Public Health system has to be streamlined to ensure high-quality service.

The aim of this study was to evaluate the influence of the institutional APR volume on the short-term outcomes and costs in the Brazilian Public Health system.

Materials and methods

Study design and population

This population-based study evaluated the number of surgical procedures performed by institutions in the Brazilian Public Health system from January/2010 to July/2022. Data were extracted from a public domain from the informatics departments of the Brazilian Public Health system (DATASUS).

We included the SUS Procedures, Medicines and OPM Table Management System (SIGTAP) identifiers "perineal amputation" (04.07.02.001-2), and "oncologic perineal amputation" (04.16.05.001-8). All hospitals supported by the SUS were included.

Extracted variables and outcomes

The number of hospitalizations by patient identifier, the Hospitalization Authorization (AIH) was obtained from the TabNet/DATASUS. The length of hospital stay (LOS), length of stay in the intensive care unit (ICU), the number of in-hospital deaths, and the personnel and hospital costs for each hospitalization were also extracted.

The population size for each Brazilian federal unit was estimated based on data from the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística, 2015*).

Costs analysis

Differences in personnel, hospital and total direct costs for each APR-related hospitalization were estimated according to the data extracted from TabNet/DATASUS. Only in-hospital costs were estimated. The TabNet/DATASUS provides a macro-costing assessment of direct costs from the health system perspective. Costs were expressed in the Brazilian currency (Real; R$) and United States dollars (US$), and were adjusted for inflation, estimated by the Broad Consumer Price Index (IPCA).

Statistical analysis

The number of APR-related hospitalizations for each Brazilian federal unit was expressed by population size (per 100,000 inhabitants). The incidence graph was generated with the TabNet/DATASUS software.

The correlations between the surgical volume and the length of hospital stay, ICU stay, personnel costs, hospital costs, total costs, and in-hospital mortality were evaluated using linear correlation analysis. A robust HC3 standard error was applied. Scatter plots with the corresponding fit lines were created.

We also compared the high-volume and low-volume institutions. Student's *t* test was used to assess differences between groups for continuous variables assuming unequal variances. We considered high-volume institutions to average at least 5 rectal amputations per year from January/2010 to July/2022, corresponding to the top 5% of surgical volume hospitals.

A 0.05 significance level was adopted. Statistical analyses were performed with the STATA software, version 16.0 (StataCorp LLC).

Ethics

The local Ethics Committee approved the study, which waived the informed consent forms (SGPP 5338-22). Raw data are publicly available.

Results

Four hundred and twelve hospitals performed APR and were included. The total number of hospitalizations for APR was 7926, with 270 in-hospital deaths. The highest number of procedures per population was recorded in São Paulo State, with 6.26 rectal amputations per 100,000 inhabitants (see Fig. 1).

The linear regression model showed that the number of hospital admissions for APR were negatively associated with in-hospital mortality (Coef.: − 0.001; $p = 0.013$) and length of ICU stay (Coef.: − 0.006; $p = 0.01$). The number of hospital admissions was not significantly associated with personnel (Coef.: − 2.333; $p = 0.367$), hospital (Coef.: − 11.811; $p = 0.292$), and total costs (Coef.: − 14.117; $p = 0.305$). Table 1 details the regression analysis, and Fig. 2 shows the scatter plot with the corresponding fit regression models (see Table 2, Fig. 3).

Twenty-three hospitals, on average, performed at least 5 APRs per year and were considered the top 5% of

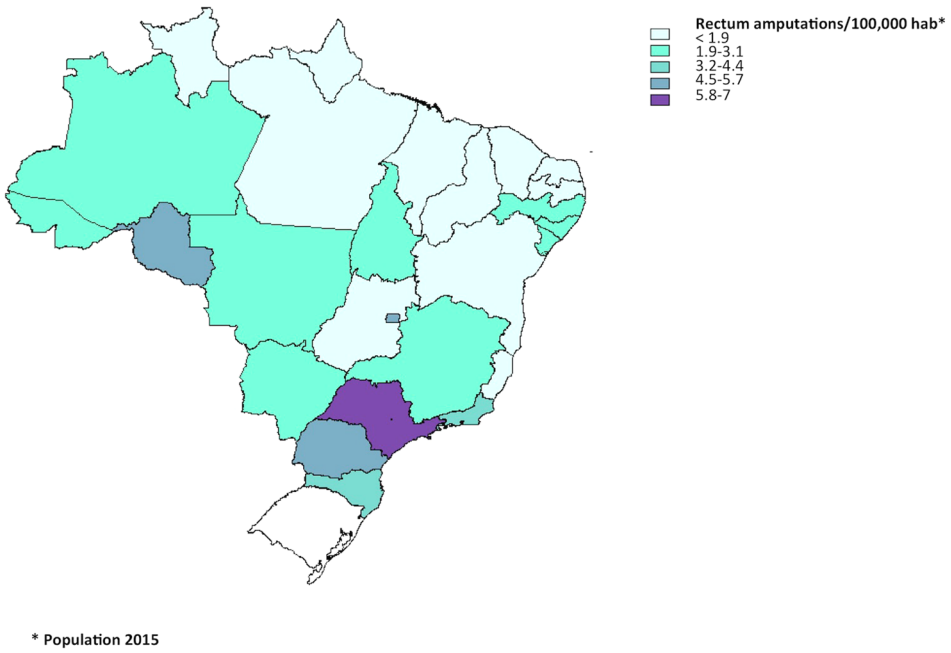

Fig. 1 Number of rectal amputations per 100,000 inhabitations during the period 2010–2022 across the Brazilian federative units (estimation of the population size according with the Brazilian Institute of Geography and Statistics – IBGE; 2015)

Table 1 Linear regression model

	Coef.	Robust HC3 SE	*p*-value
Age (years)	0.012	0.009	0.166
In-hospital mortality	> – 0.001	< 0.001	0.013
LOS (ICU) (days)	– 0.006	0.002	0.010
LOS (days)	0.001	0.008	0.889
Personnel costs	– 2.333	2.583	0.367
Hospital costs	– 11.811	11.195	0.292
Total costs	– 14.117	13.771	0.305

LOS length of stay, *ICU* intensive care unit, *SE* standard error

Significant *p* values are highlighted

Table 2 Comparisons of the high-volume (≥ 5 rectal amputations per year) and low-volume institutions (< 5 rectal amputations per year)

	High-volume (*n* = 23)		Low-volume (*n* = 389)		Difference		
	Mean	SE	Mean	SE	Mean	SE	*p*-value
Mean number of hospitalizations per year for APR	10.4	1.267	1.09	0.061	9.33	1.268	< 0.001
Age (years)	60.577	0.489	60.086	0.538	0.491	0.727	0.501
In-hospital mortality	0.025	0.003	0.059	0.009	– 0.034	0.009	< 0.001
LOS (ICU) (days)	1.235	0.183	1.791	0.146	– 0.556	0.234	0.021
LOS (days)	10.806	1.042	10.222	0.337	0.584	1.095	0.598
Personnel costs (R$/US$)	952.23/186.64	49.40/9.68	1129.04/221.29	165.03/32.35	– 176.81/-34.65	172.26/33.76	0.305
Hospital costs (R$/US$)	4078.39/799.36	219.78/43.08	4987.39/977.53	1054.02/206.59	– 909.00/-178.16	725.63/142.22	0.111
Total costs (R$/US$)	5030.63/986.00	266.49/52.23	6116.71/1198.88	855.95/167.77	– 1986.08/-389.27	896.47/175.71	0.226

Costs are expressed in real (R$) and United States dollars (US$)

APR abdominoperineal resection, *LOS* Length of stay, *ICU* intensive care unit, *SE* standard error

Significant *p* values are highlighted

high-volume institutions. These high-volume hospitals were responsible for 2875 APRs, while low-volume institutions (< 5 rectal amputations per year) accounted for 5051 APRs. The in-hospital mortality in high-volume institutions was significantly lower than in low-volume institutions (2.5 vs. 5.9%; mean difference: – 3.4%; $p < 0.001$). The mean length of ICU stay was also lower in high-volume institutions (1.23 vs. 1.79 days; mean difference: – 0.58 day; $p = 0.021$). In

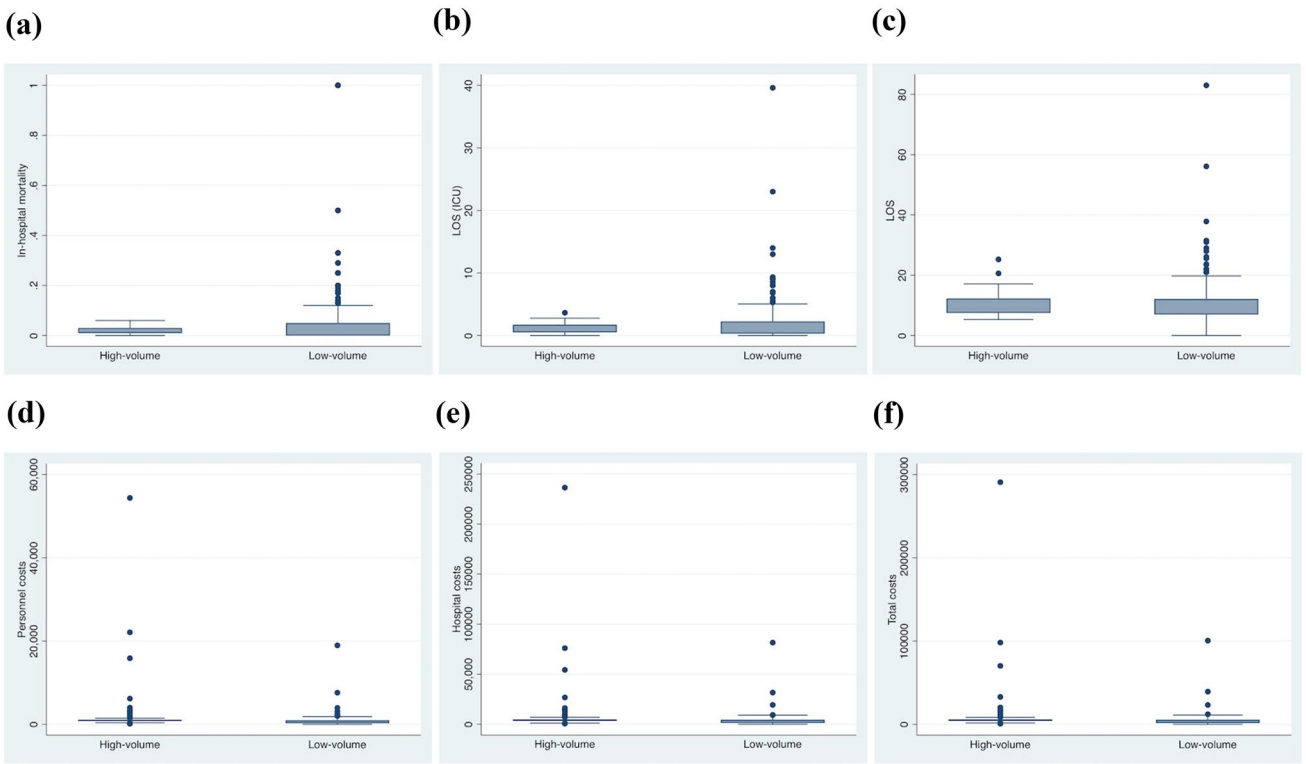

Fig. 2 Scatter plot with the corresponding fit regression model, showing the association of the number of hospitalizations for rectal amputations during the period 2010–2022. **a** Length of stay in the intensive care unit; **b** length of hospital stay; **c** in-hospital mortality; **d** personnel costs; **e** hospital costs; **f** total costs

high-volume institutions, the personnel (R$ 952.23 [US$ 186.64] vs. R$ 11,129.04 [US$ 221.29]; mean difference: R$ − 176.81 [US$ − 34.65]; $p = 0.305$), hospital (R$ 4078.39 [US$ 799.36] vs. R$ 4987.39 [US$ 977.53]; mean difference: R$ − 909.00 [US$ − 178.16]; $p = 0.111$), and total costs (R$ 5030.63 [US$ 986.00] vs. R$ 6116.71 [US$ 1198.88]; mean difference: R$ − 1986.08 [US$ -389.27]; $p = 0.226$) were lower.

Discussion

The findings of this nationwide study showed that high institutional APR volume is associated with lower in-hospital mortality and less demand for intensive care, without increasing demand for funding expenses, in the context of the Brazilian Public Health system. Policymakers and insurance companies should infer that high-complexity procedures, including rectal amputation, should be centralized to streamline outcomes, mainly in large public systems. An inconvenience of centralizing APRs is the indirect costs related to patients' mobility to the high-volume centers. This issue is especially important in very large countries, such as Brazil.

Previously published studies also found an association between postoperative outcomes and hospital surgical volume. In a systematic review, Huo et al. [10] showed that the pooled 30-day postoperative mortality was significantly lower in institutions with higher colorectal surgery volume than in lower volume institutions (HR: 0.83; 95% CI 0.78–0.87). Subgroup analysis of rectal surgery alone also showed this correlation (HR: 0.81; 95% CI 0.74–0.89). The 5-year overall survival of patients treated at high-volume institutions was also significantly higher in colorectal surgery (HR: 0.91; 95% CI 0.87–0.94).

However, no previously published nationwide study evaluated the APR volume, surgical outcomes, and costs. APR differs extensively from other colorectal resections. It is a technically challenging procedure due to the inherent risks associated with the neighboring major vessels, presacral venous plexus, urinary and reproductive tracts, and pelvic nerves. The risk of a complication occurring is over 45% [11]. Some of the most common postoperative complications are iatrogentic injuries to pelvic organs, abscesses, wound-healing complications, and perineal dehiscence [4, 5]. These complications impact the usage of intensive care facilities and, consequently, increase costs.

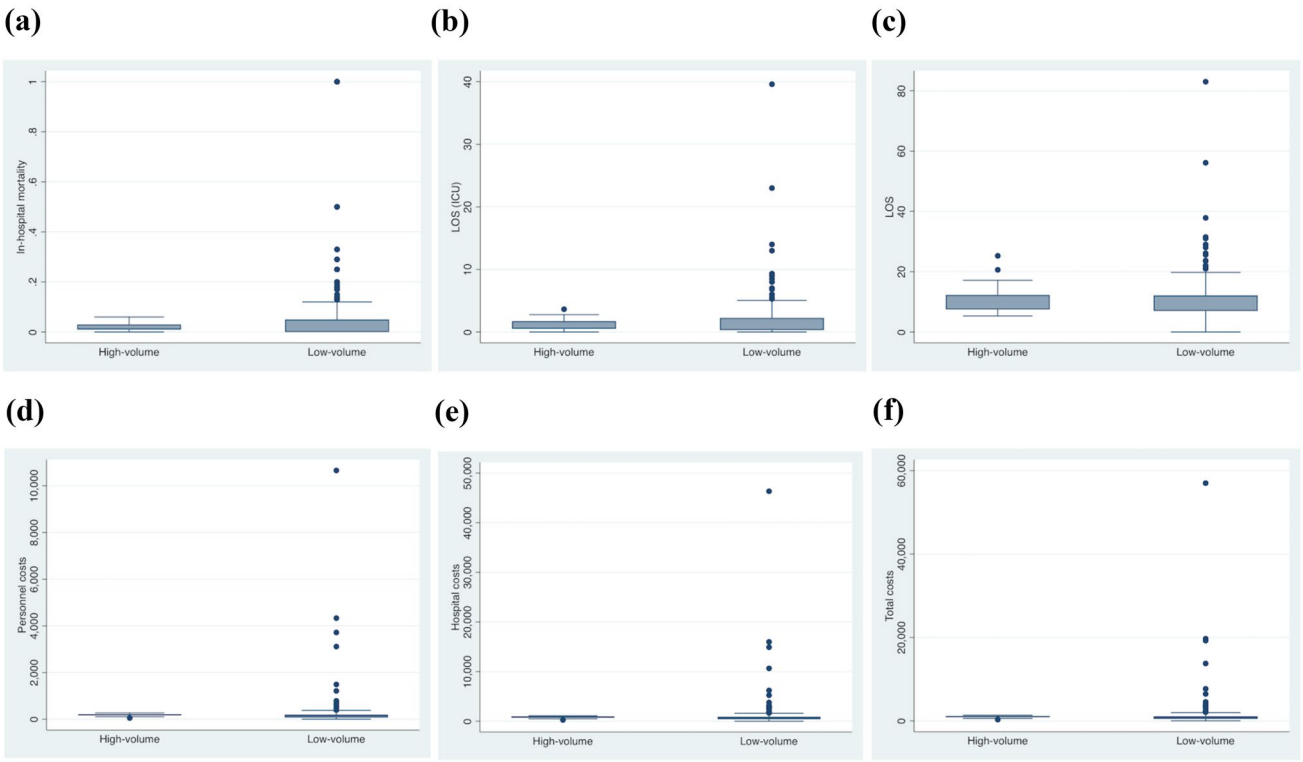

Fig. 3 Box plot, comparing of the high-volume (≥5 rectal amputations per year) and low-volume institutions (<5 rectal amputations per year). **a** Length of stay in the intensive care unit; **b** length of hospital stay; **c** in-hospital mortality; **d** personnel costs; **e** hospital costs; **f** total costs. Costs are expressed in US$

Liu et al. [12] evaluated the total costs of hospitalization in colorectal surgery and found that costs were higher in high-volume hospitals (OR: 1.73; 95% CI 1.33–2.25). Some costs are unavoidable in allowing top institutions to deliver high-quality care. Rectal cancer management demands many professionals with a qualified multidisciplinary team. Oncologists, radiotherapeutics, experienced colorectal surgeons, reconstructive plastic surgeons, stomal therapeutics, and rehabilitation physiotherapists are frequently necessary during the perioperative management of APR patients. Well-equipped surgical hospitals provide ready-to-use diagnostic methods and interventional radiology. Ultrasonic, bipolar, integrated sealing, dissection methods, and other operating room innovations may reduce operating time and improve outcomes [13–15]. All these technologies have a price, and there is no way to dissociate high costs from high-quality of care. Concentrating resources in large institutions capable of managing a high volume of complex surgeries helps to mitigate expenses. Additional costs for well-equipped institutions are offset by improved outcomes and less use of intensive care. This hypothesis could explain why the current study showed no significant relation between APR volume and hospital and personnel expenses. Besides, the high complexity of the management of APR patients compared with patients who had other colorectal procedures may also explain the differences between the present study and the findings of Liu et al.[12]. Intensive care and in-hospital mortality may impact APR costs more than costs of other colorectal procedures.

The perfect cutoff point in hospital volume per year is still to be defined. There has yet to be a consensus on an optimal cutoff point, and previously published studies showed hospital's annual volume for colorectal surgery as ranging from 5 to 192 procedures [16–29]. However, these studies comprised all colorectal procedures with little mention of APR specifically. We arbitrarily used a 5 APRs per year cutoff since no previous APR study was well-defined. This cutoff point included only 5% of institutions (23 hospitals in total in Brazil). However, 5APRs per year is still a low rate for streamlining outcomes, depending on the number of surgeons in the institution. Billingsley et al. [30] advocate that the expertise of surgeons at each institution is more relevant than the overall institutional experience in predicting primary adverse outcomes following colorectal resection. However, they analyzed colon *and* rectal cancer procedures. Curative colectomy depends on successful margin free resection and, consequently, on the expertise of surgeons. Low rectal cancer management is more multimodal and depends more on the institutional specialties network, such as radiotherapy, oncology, and reconstructive plastic

surgery. The surgeon is a specialist among several other qualified professionals in an institution treating low rectal cancer. Consequently, institutional experience may impact APR outcomes more than colectomy outcomes.

This study's strength is covering the more important public population-based data worldwide. Brazil has over 200 million inhabitants, and over 70% of the population depends exclusively on the Public Health system [31]. This study included over 400 hospitals over a 12-year period. No previous study with this dataset has been published.

This study has some limitations. As with any population-based data, this study is subject to information bias due to potential registry faults [32, 33]. Furthermore, population-based data usually need more specific details of individuals' characteristics and management. DATASUS lacks data such as oncologic staging, long-term follow-up, cancer recurrence, chemo and radiotherapy, and histological findings. APRs due to squamous cell carcinoma or adenocarcinoma may have different outcomes. The lack of individual cost analysis is a source of imprecision in estimating the amounts spent on the procedures. The DATASUS estimates costs based on a unified procedure billing table (SIGTAP), which may fail to reflect with precision the costs for each hospitalization-related procedure.

Another issue is that APR was mainly performed in the Brazilian state of São Paulo, the region contributing most to the Brazilian gross domestic product. The heterogeneity of the availability of resources across Brazil may be a source of bias. Future community-based clinical trials are warranted, comparing institutions with high and low-APR volume and evaluating short-and long-term outcomes with micro-costing estimation. Moreover, future studies should determine the ideal volume number per institution to provide optimized outcomes.

Conclusions

Higher institutional APR volume is associated with lower in-hospital mortality and less demand for intensive care. The findings of the present nationwide study may affect how Public Health manages APR care.

Funding The study was not funded.

Declarations

Conflict of interest None.

Ethical and Informed Consent The local Ethics Committee approved the study, which waived the informed consent forms (SGPP 5338-22). Rawdata are publicly available.

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