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Original article

Assessing the regional policies of Italian regions in managing the Cesarean delivery phenomenon: a fractal analysis

Ugo Indraccolo[1], Beatrice Bianchi[2], Chiara Borghi[2], Pantaleo Greco[2]

[1]Maternal-Infantile Department, Complex Operative Unit of Obstetrics and Gynecology, "Alto Tevere" Hospital of Città di Castello - ASL 1 Umbria; [2]Department of Medical Sciences, Section of Obstetric and Gynaecology, University of Ferrara, Ferrara, Italy.

Abstract

Objectives. Assessing the 2017 administrative data on Cesareans delivery in Italy by using fractal statistic. Methods. 2017 administrative data on Italian Cesarean deliveries are freely available as crude numbers and rates according to each Italian region, according to Italian health institute type and according to first or repeated Cesarean. As already reported, the Italian Cesarean delivery phenomenon is in relationship with hospital, regional, cultural perspectives in caring pregnancy and delivery. Fractal statistics can best assess the biocomplexity underlying the Italian Cesarean section phenomenon. Fractal shapes and self-organized criticality of the Cesarean section phenomenon for each Italian region were done. Fractal shapes were compared to find similarities by using global test of coincidence among regression lines. Results. In the regions where the health care institutes are more than a type, there are evanescent similar fractal shapes. Self-organized criticality assessment demonstrates that chaos is largely involved in Cesarean delivery phenomenon in all Italian regions and in Italy. The fractal images for each region are able to highlight the item causing the deviation from fractal shapes in each region. Conclusion. Fractal statistics could be used to compare regional or hospital policies in performing Cesareans, starting from Cesareans rates extracted from administrative data. (www.actabiomedica.it)

Key words: Cesarean section, hospital policies, fractal statistic.

Introduction

The 3 of April 2019, the 2017 administrative data of deliveries in Italy were published (1). The data were produced according to the mode of delivery (Cesarean delivery, non-Cesarean delivery), according to the type of health institution in which the deliveries have occurred and according to Italian regions. The topic is of special interest in Italy, where the Cesarean section rate has been higher than 30%. Remarkable, Cesarean section rate higher than 30% could increase maternal and neonatal mortality (2, 3). Cesarean section rates are in relationship with heterogeneous policies of caring pregnant and laboring women in Italy. Therefore, hospital standards and policies (4), along with regional cultural perspectives on Cesarean section, influence the rates of Cesareans (5). As a logical consequence, it's hard to compare the Cesarean section rates among Italian regions for providing a unequivocal point of view (6).

By reading the 2017 administrative data on surgical delivery in Italy, it could be understood that each Italian region has an own behavior in managing the Cesarean delivery (1). If one would be able of build

images of regional behavior in managing Cesarean section, one could also compare those images one by one, aiming to find similarities or dissimilarities.

Fractal statistics can be useful to build such images. To date, fractal statistics for describing and assessing biocomplexity has been proposed by Authors (7). The assumption for applying the fractal statistics is that the complexity of biomedical processes is in relationship with time and place. Therefore, assessing the same biomedical process needs either different time frames in the same place, or different places in the same time frame. The latter, is what reported in the 2017 administrative data on Cesarean delivery in Italy.

The aim of this report is to build fractal images of the Cesarean deliveries for Italian regions and to compare them one by one and with the overall Italian image.

Materials and methods

The 2017 administrative data on Cesarean delivery in Italy were freely available from (1). They were reported in Table 1. The Italian health institutes are grouped as public institutes (group I and group II), accredited private institutes (group I and group II) and

Table 1. Rates of Cesareans: 2017 administrative data (modified from [1]).

	Public health institutes				Private accredited institutes				Non-accredited private institutes	
	Group I		Group II		Group I		Group II			
	First Cesarean	Repeated Cesarean	First Cesarean	Repeated Cesarean	First Cesarean	Repeated Cesarean	First Cesarean	Repeated Cesarean	First Cesarean	Repeated Cesarean
Piemonte	19.7%	0.5%	16.7%	8.9%						
Valle d'Aosta			17.5%	10.4%						
Lombardia	26.7%	2.6%	16.6%	8.3%	20.2%	7.5%	19.5%	8.0%	10.0%*	10.0%*
Bolzano area			17.2%	7.4%						
Trento area			13.6%	8.4%						
Veneto	22.3%	10.0%	14.1%	6.5%	17.1%	7.6%				
Friuli V. Giulia	16.4%	5.7%	16.9%	5.5%			17.8%	5.2%		
Liguria	26.9%	12.1%	16.7%	9.4%	20.8%	11.3%				
Emilia Romagna	19.0%	1.2%	16.7%	7.3%						
Toscana	25.5%	9.1%	16.5%	7.3%					37.5%	25.0%
Umbria	18.4%	8.8%	18.0%	9.7%						
Marche	24.1%	13.3%	19.9%	11.1%						
Lazio	26.9%	14.3%	21.7%	12.4%	23.7%	12.5%	27.0%	15.0%	47.1%	15.2%
Abruzzo			20.8%	14.1%						
Molise			24.0%	18.1%						
Campania	23.7%	21.0%	26.6%	24.1%	25.2%	19.8%	30.0%	32.3%		
Puglia	22.9%	7.1%	24.3%	18.7%	21.5%	14.9%	29.4%	11.0%		
Basilicata	22.5%	6.8%	20.9%	13.3%						
Calabria	24.5%	12.5%	23.0%	14.0%			22.1%	12.4%		
Sicilia	23.6%	18.8%	21.9%	16.7%	23.5%	18.7%	25.8%	25.7%		
Sardegna	28.9%	12.5%	21.0%	12.1%			32.5%	18.2%		
ITALY	23.2%	12.9%	18.6%	11.1%	22.6%	12.9%	27.2%	23.1%	45.4%	16.4%

Data are reported as rates, according to the type of health care institute in Italy for each Italian region and for Italy.
*The rates were estimated according to Quigley et al [8].

Table 2. Types of health care institutes.

	Group I	**Group II**
Public health institutes	• Health companies • Health – University companies • Public polyclinics • Scientific Institutes of Recovery and Care • Public foundations	Self administered hospitals
Private accredited institutes	• Private polyclinics • Private Scientific Institutes of Recovery and Care • Private foundations • Religious hospitals • Private hospitals • Research organizations	Private accredited nursing home
Non-accredited institutes	Private non-accredited nursing home	

The health care institutes are listed.

non-accredited private institutes. The characteristics of each group are listed in Table 2 and have been established by Italian law. Summarizing, the main differences among institutes in Italy are in relationship to the funding received by institutes. The public institutes are supported by Governmental funds, while private accredited institutes receive Governmental funds for providing same health services than public institutes, along with health services directly paid by patients or by private funds. The non-accredited private institutes provided health services paid by patients. The standards of care are ensured by Governmental surveillance.

The steps of fractal statistics were the following.

- It was estimated the self-affinity parameter (called lambda, or λ) of the fractal shape by the rates of Cesarean section (repeated or not) for Italian regions and for Italy overall. According to Baldado et al (9), the rule applied was $\lambda=1+n[\Sigma\ ^{n}_{i=1}\ ln(x_i/\theta)]^{-1}$ where x_i is the rate of Cesarean deliveries in each health care institute, θ is the median Cesarean delivery rate, and n the number of all rates observed. The rates of the whole Italian Cesarean deliveries were calculated from all crude data. Italian region with only a type of health care institute cannot be encompassed in fractal statistics because the biocomplexity in relationship with health care institutes cannot be applied. Therefore, such regions have not been assessed in fractal analysis.
- The fractal dimension was calculated (9) as $d=\log\lambda n/\log\lambda$.
- It was assessed if the Cesarean section rates describe a fractal image for each region of Italy and for Italy. The Theorem 2, reported by Baldado et al (9) was applied. The rule is $[x_i/(1-d)]=k$. If the Cesarean section rates depict a fractal shape, the k values calculated for each x_i should be similar. To test it, the values were transformed by applying the Γ function. Those transformed values were plotted, and regression lines were calculated. For each Γ(k) series, the regression line should be coincident with a horizontal line crossing the mean value of Γ(k) series. An intercept test was used for inference ($p<0.05$ for significance).
- As additional calculations of fractal analysis, Zipf' test and level of noise have been calculated. The Zipf' test was performed on the log Cesarean section rates of each health institute in each Italian region and in Italy. The level of noise (beta or β) was calculated according to Glattre et al (7): $\beta=2\lambda-1$. To test if the Zipf'

line is significant, it was tested if the deviation from linearity of the plotted log rates of the Zipf' test is significant. If it is significant, the Zipf' test is considered negative. The level of noise was disclosed according to what reported by Glattre et al (7): white ($\beta=0$), pink ($0<\beta<2$), brown ($\beta=2$), black ($\beta>2$). Having a level of noise from white to pink was considered appropriate for meeting one of the Bak' criteria for proving the self organized criticality (7), meaning no chaotic influence. The other ones Bak' criteria are: proved fractal shape and Zipf' test positive (7).

- As a final step, the fractal images of each region were compared one by one and with the fractal image of Italy. It was applied a global test of coincidence between regression lines calculated on the cumulative distribution of x (9): $f(x)=1-(x_i/\theta)^{1-\lambda}$. If the test proves that the regression lines are coincident, the fractal images are similar. The null hypothesis is that the regression lines are coincident. The p level for accepting the null hypothesis was set at $p\geq0.80$.
- It was also analyzed the data set by applying the Cochrane's Q-statistic, aiming to assess differences between fractal statistic and Q-statistic. The effect size was established as the proportion of Cesarean section rate, and was encoded according to Lipsey et al (10). The Cochrane's Q-statistic assesses the heterogeneity among samples. Thus, it was expected that a low heterogeneity index (I^2) means similar behavior in managing the Cesarean delivery among Italian regions, while higher heterogeneity index means different behavior in managing Cesarean delivery among Italian regions. A I^2 of more than 60% was considered heterogeneous.

Results

Table 3 reported the $\Gamma(k)$ values of Italian regions and for Italy. The regions with no more than a kind of health institute are not reported. They are Valle d'Aosta, Trento area, Bolzano area, Abruzzo, Molise.

The intercept test for the $\Gamma(k)$ values is significant for the Campania region, proving that the shape built for Camapania is not fractal. Table 4 reports the Bak' criteria for self organized criticality. The level of noise is high for all regions and for Italy. The Lombardia, Veneto, Liguria, Lazio, Puglia and Italy have also a Zipf' test negative.

The Q-statistic for the whole Italy (excluding the Valle d'Aosta, Trento area, Bolzano area, Abruzzo, Molise data) is: Q=56082.8 with I^2 99.99%. Moreover, the heterogeneity is not improved if the Q-statistic is performed by excluding the Camapania region (non fractal shape): Q=59124.86 with I^2 99.99%.

The fractal shapes comparisons (with the high level of probability set at 80%) find similarities between Basilicata and Calabria, and between Emilia Romagna and Sicilia. Table 5 provides the p values for each comparison. By taking a lower level of p, evanescent similarities can be found for more regions.

Figure 1 shows trends of the cumulative distributions of x ($f(x)=1-(x_i/\theta)^{1-\lambda}$) for each region. The fractal shapes lose their self-similarity in some points; identifying which is the institutions group responsible of abnormal treatment of Cesarean delivery (the first Cesareans or the repeated Cesareans). For example, in the Puglia region, the repeated Cesarean section in type II health institute causes the lost of the self-similarity, while in the Friuli V. Giulia seems to have same self-similarity for each institute in both first and repeated Cesareans. Figure 2 provides the fractal shape of Italy.

Discussion

The study demonstrates that the Cesarean section phenomenon in Italy is widely chaotic in each region. Similarities were found for only 4 regions. However, evanescent similarities can be seen for many other regions (Figure 1). Figure 1 illustrates the shapes for each region, identifying where each shape loses its self-similarities. This finding cannot be proved by the Q-statistic. The heterogeneity observed with Q-statistic demonstrates that there is not homogeneous rates of Cesarean sections (confirming chaos), leading to conclude that there are different behaviors of managing

Table 3. Γ(k) values distributions.

Region	Health care institutes	Γ(k)	Intercept test
Piemonte	Public health institutes		
	Group I: First Cesarean	-3.598	n.s.
	Repeated Cesarean	-88.843	
	Group II: First Cesarean	-3.810	
	Repeated Cesarean	-5.782	
Lombardia	Public health institutes		
	Group I: First Cesarean	-4.329	n.s.
	Repeated Cesarean	-34.869	
	Group II: First Cesarean	-6.167	
	Repeated Cesarean	-11.411	
	Accredited private health institutes		
	Group I: First Cesarean	-5.273	
	Repeated Cesarean	-12.545	
	Group II: First Cesarean	-4.419	
	Repeated Cesarean	-11.809	
	Non-accredited private health institutes		
	First Cesarean	-9.609	
	Repeated Cesarean	-9.609	
Veneto	Public health institutes		
	Group I: First Cesarean	-3.757	n.s.
	Repeated Cesarean	-6.488	
	Group II: First Cesarean	-4.942	
	Repeated Cesarean	-9.478	
	Accredited private health institutes		
	Group I: First Cesarean	-4.328	
	Repeated Cesarean	-8.232	
Friuli V. Giulia	Public health institutes		
	Group I: First Cesarean	-4.447	n.s.
	Repeated Cesarean	-10.692	
	Group II: First Cesarean	-4.361	
	Repeated Cesarean	-11.052	
	Accredited private health institutes		
	Group II: First Cesarean	-4.222	
	Repeated Cesarean	-11.644	
Liguria	Public health institutes		
	Group I: First Cesarean	-3.578	n.s.
	Repeated Cesarean	-5.683	
	Group II: First Cesarean	-4.480	
	Repeated Cesarean	-7.010	
	Accredited private health institutes		
	Group I: First Cesarean	-3.932	
	Repeated Cesarean	-6.006	

(Continued)

Table 3. Γ(k) values distributions (Continued)

Region	Health care institutes	Γ(k)	Intercept test
Emilia Romagna	Public health institutes		
	Group I: First Cesarean	-3.632	n.s.
	Repeated Cesarean	-37.377	
	Group II: First Cesarean	-3.810	
	Repeated Cesarean	-6.815	
Toscana	Public health institutes		
	Group I: First Cesarean	-3.596	n.s.
	Repeated Cesarean	-7.030	
	Group II: First Cesarean	-4.429	
	Repeated Cesarean	-8.534	
	Non-accredited private health institutes		
	First Cesarean	-3.961	
	Repeated Cesarean	-3.614	
Umbria	Public health institutes		
	Group I: First Cesarean	-3.668	n.s.
	Repeated Cesarean	-5.835	
	Group II: First Cesarean	-3.696	
	Repeated Cesarean	-5.401	
Marche	Public health institutes		
	Group I: First Cesarean	-3.573	n.s.
	Repeated Cesarean	-4.314	
	Group II: First Cesarean	-3.510	
	Repeated Cesarean	-4.879	
Lazio	Public health institutes		
	Group I: First Cesarean	-4.128	n.s.
	Repeated Cesarean	-6.584	
	Group II: First Cesarean	-4.746	
	Repeated Cesarean	-7.442	
	Accredited private health institutes		
	Group I: First Cesarean	-4.467	
	Repeated Cesarean	-7.390	
	Group II: First Cesarean	-4.119	
	Repeated Cesarean	-6.326	
	Non-accredited private health institutes		
	First Cesarean	-3.610	
	Repeated Cesarean	-6.256	
Campania	Public health institutes		
	Group I: First Cesarean	-3.556	p=0.033
	Repeated Cesarean	-3.652	
	Group II: First Cesarean	-3.560	
	Repeated Cesarean	-3.550	
	Accredited private health institutes		
	Group I: First Cesarean	-3.544	
	Repeated Cesarean	-3.728	
	Group II: First Cesarean	-3.709	
	Repeated Cesarean	-3.917	

Table 3. Γ(k) values distributions (Continued)

Region	Health care institutes	Γ(k)	Intercept test
Puglia	Public health institutes		
	Group I: First Cesarean	-3.981	n.s.
	Repeated Cesarean	-10.018	
	Group II: First Cesarean	-3.863	
	Repeated Cesarean	-4.499	
	Accredited private health institutes		
	Group I: First Cesarean	-4.123	
	Repeated Cesarean	-5.303	
	Group II: First Cesarean	-3.602	
	Repeated Cesarean	-6.789	
Basilicata	Public health institutes		
	Group I: First Cesarean	-3.545	n.s.
	Repeated Cesarean	-7.245	
	Group II: First Cesarean	-3.559	
	Repeated Cesarean	-4.314	
Calabria	Public health institutes		
	Group I: First Cesarean	-3.634	n.s.
	Repeated Cesarean	-5.413	
	Group II: First Cesarean	-3.711	
	Repeated Cesarean	-4.968	
	Accredited private health institutes		
	Group II: First Cesarean	-3.771	
	Repeated Cesarean	-5.447	
Sicilia	Public health institutes		
	Group I: First Cesarean	-3.919	n.s.
	Repeated Cesarean	-4.483	
	Group II: First Cesarean	-4.079	
	Repeated Cesarean	-4.869	
	Accredited private health institutes		
	Group I: First Cesarean	-3.928	
	Repeated Cesarean	-4.499	
	Group II: First Cesarean	-3.762	
	Repeated Cesarean	-3.768	
Sardegna	Public health institutes		
	Group I: First Cesarean	-3.548	n.s.
	Repeated Cesarean	-5.413	
	Group II: First Cesarean	-3.858	
	Repeated Cesarean	-5.553	
	Accredited private health institutes		
	Group II: First Cesarean	-3.615	
	Repeated Cesarean	-4.166	

(Continued)

Table 3. Γ(k) values distributions (Continued)

Region	Health care institutes	Γ(k)	Intercept test
ITALY	Public health institutes		
	Group I: First Cesarean	-5.443	n.s.
	Repeated Cesarean	-8.975	
	Group II: First Cesarean	-6.514	
	Repeated Cesarean	-10.294	
	Accredited private health institutes		
	Group I: First Cesarean	-5.556	
	Repeated Cesarean	-8.975	
	Group II: First Cesarean	-4.829	
	Repeated Cesarean	-5.461	
	Non-accredited private health institutes		
	First Cesarean	-3.643	
	Repeated Cesarean	-7.254	

Γ(k) distributions are reported according to Italian regions and health care institute type. The significance of intercept' test is also reported.

Table 4. Self organized criticality assessment.

Italian region	Fractal	Zipf' test Significance	Noise (beta)	Self organized criticality
Piemonte	Yes	+ n.s.	Black (2.951)	No
Lombardia	Yes	- p=0.002	Black (4.806)	No
Veneto	Yes	- p<0.001	Black (3.869)	No
Friuli V.Giulia	Yes	+ n.s.	Black (3.962)	No
Liguria	Yes	- p<0.001	Black (2.957)	No
Emilia Romagna	Yes	+ n.s.	Black (2.971)	No
Toscana	Yes	+ n.s.	Black (3.983)	No
Umbria	Yes	+ n.s.	Black (2.879)	No
Marche	Yes	+ n.s	Black (2.833)	No
Lazio	Yes	- p=0.001	Black (4.835)	No
Campania	No	+ n.s.	Black (4.002)	No

Table 4. Self organized criticality assessment. (Continued)

Puglia	Yes	- p=0.023	Black (5.007)	No
Basilicata	Yes	+ n.s.	Black (2.927)	No
Calabria	Yes	+ n.s.	Black (3.892)	No
Sicilia	Yes	+ n.s.	Black (4.914)	No
Sardegna	Yes	+ n.s.	Black (3.832)	No
ITALY	Yes	- p=0.006	Black (4.717)	No

Bak' criteria for the self organized criticality [7] are reported. The regions without more than a type of health care institute are not reported.

the Cesarean section phenomenon. This is mainly due to different rates of Cesareans. Differently, the fractal statistics, checking for similarities among shapes, is able to depict both similar behavior and chaos involvement, despite different overall rates of Cesareans.

To date, the concern about the assessment of Cesarean section rates has pushed to order the Cesarean sections according to the type of patients underwent surgical delivery. This is the well know Robson' classification (11). The Robson' classes are useful to compare Cesarean sections among hospitals, regions, countries (12,13). The Robson' classification, however, is only able to mach the rates of classes, but it cannot provide the image of the overall policies of conceding the Cesarean section. Critical issues of hospitals and health system (5,14-19), along with perspectives of patients (20,21), obstetricians, and other stakeholders (5,22) could condition the behavior of performing the Cesarean sections in each Robson' classes. By applying a fractal statistics to the rate of Cesareans according to Robson classes, it could be best compared the trend of the overall hospital or regional behavior in conceding the Cesareans.

In conclusion, fractal statistics applied to administrative data on Cesarean section is able to provide an image of the surgical delivery biomedical process. It can also easily identify the items responsible of the chaotic shapes, where health managers can intervene.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

Table 5. Coincidence test results.

	Lombardia	**Veneto**	**Friuli V. G.**	**Liguria**	**E. Romagna**	**Toscana**	**Umbria**	**Marche**	**Lazio**	**Puglia**	**Basilicata**	**Calabria**	**Sicilia**	**Sardegna**	**ITALY**
Piemonte	0.019	<0.001	0.435	0.097	0.441	0.278	0.447	<0.001	0.019	0.446	0.502	0.588	0.553	<0.001	0.360
Lombardia		<0.001	0.024	0.192	0.037	0.052	0.097	<0.001	0.293	0.213	0.160	<0.001	0.240	<0.001	0.124
Veneto			<0.001	<0.001	<0.001	<0.001	<0.001	0.041	<0.001	<0.001	<0.001	0.532	0.414	<0.001	<0.001
Friuli V. G.				0.591	0.435	0.122	0.261	<0.001	0.024	0.058	0.435	0.234	0.408	<0.001	0.255
Liguria					0.143	0.170	0.250	<0.001	0.797	0.336	0.343	<0.001	0.400	<0.001	0.239
E. Romagna						0.286	0.447	<0.001	0.037	0.446	0.504	0.588	0.941	<0.001	0.360
Toscana							0.032	<0.001	0.052	0.384	0.525	0.687	0.420	<0.001	0.263
Umbria								<0.001	0.097	0.156	0.447	0.588	0.565	<0.001	0.097
Marche									<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lazio										0.213	0.160	<0.001	0.240	<0.001	0.124
Puglia											0542	0.126	0.301	<0.001	0.167
Basilicata												0.805	0.553	0.588	0.360
Calabria													0.127	<0.001	0.065
Sicilia														<0.001	0.240
Sardegna															<0.001

p values for the coincidence tests. The p values represent the likelihood that the regression lines are coincident (meaning similarities among shapes). The p value set to be significant has been ≥80%: significant results have been highlighted in bold.

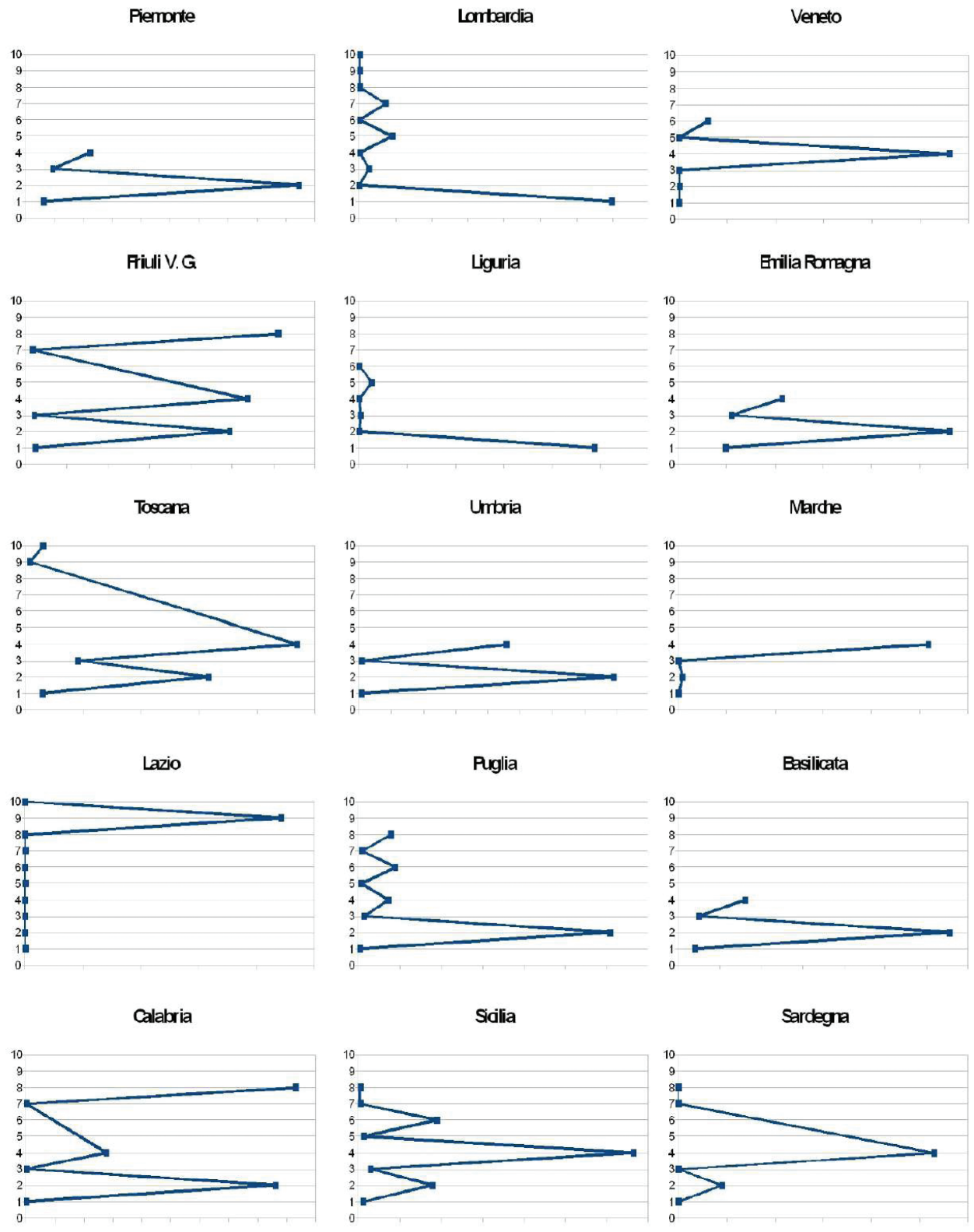

Figure 1. Images of the cumulative distributions for each region with fractal shape. On the ordinate axis: 1=Public health institutes (Group I) – First Cesarean; 2=Public health institutes (Group I) – Repeated Cesarean; 3=Public health institutes (Group II) – First Cesarean; 4=Public health institutes (Group II) – Repeated Cesarean; 5=Accredited private health institutes (Group I) – First Cesarean; 6=Accredited private health institutes (Group I) – Repeated Cesarean; 7=Accredited private health institutes (Group II) – First Cesarean; 8=Accredited private health institutes (Group II) – Repeated Cesarean; 9=Non-accredited private health institutes – First Cesarean; 10=Non-accredited private health institutes – Repeated Cesarean.

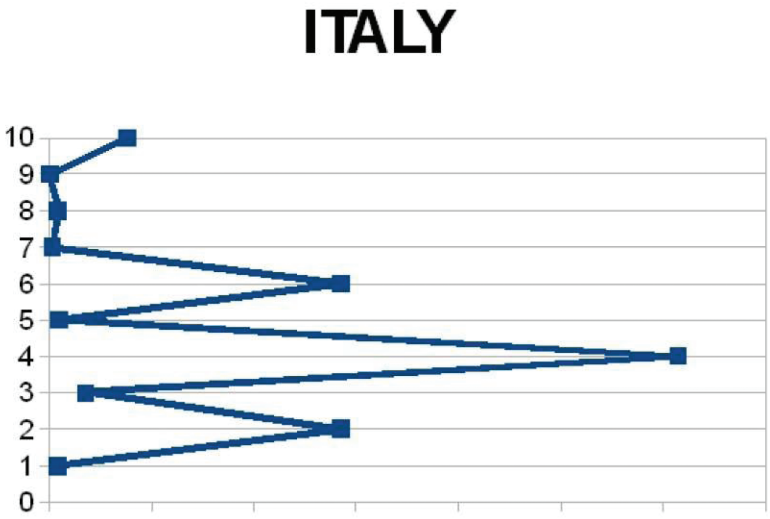

Figure 2. Image of Italy. On the ordinate axis: 1=Public health institutes (Group I) – First Cesarean; 2=Public health institutes (Group I) – Repeated Cesarean; 3=Public health institutes (Group II) – First Cesarean; 4=Public health institutes (Group II) – Repeated Cesarean; 5=Accredited private health institutes (Group I) – First Cesarean; 6=Accredited private health institutes (Group I) – Repeated Cesarean; 7=Accredited private health institutes (Group II) – First Cesarean; 8=Accredited private health institutes (Group II) – Repeated Cesarean; 9=Non-accredited private health institutes – First Cesarean; 10=Non-accredited private health institutes – Repeated Cesarean.

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Correspondence:
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Ugo Indraccolo, MD, PhD, Via Paolo Veronese 2/c, 06024 Gubbio (PG), Italy, e-mail: ugo.indraccolo@libero.it