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Cost Analysis on Imaging Diagnostic Techniques in Cerebral and Abdominal Neonatal Pathology

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Abstract: *Background*: Improvement of health care quality and cost control are the main aims of the health care reform in Romania. *Objective*: The aims of the research are to analyse the trend of costs for imaging techniques used as diagnostic tools for cerebral and abdominal neonatal pathology and to study the relationship between cost and diagnostic benefits. *Design*: This is a retrospective observational study design without a control group, conducted in the Radio-Imaging Department, Cluj District University Hospital, Romania, from October 2000 to February 2006. *Patients*: The study population was represented by neonates investigated in the Radio-Imaging Department, Cluj District University Hospital. *Intervention*: Five imaging diagnostic techniques used in the diagnosis of cerebral and abdominal neonatal pathology were investigated. *Measurements*: The costs of the investigated techniques were calculated. The concordance between clinical and imaging diagnostic was recorded. *Results*: Magnetic resonance proved to be the most expensive investigation. The rate between the raising of costs on investigation type on year was constant. The average cost of imaging investigations for patients with identified pathological aspects (€ 42.72) was not statistically significant ($p > 0.05$) compared with the average cost for patients with no pathologic imaging aspects (€ 37.62). The concordance between the clinical suspicion and the radio-imaging diagnosis was of 52.35%. *Conclusions*: The raise of radio-imaging investigation costs had a decreasing tendency over the years studied, decrease explained by the stabilization of the Romanian monetary market. The results on concordance analysis lead to the necessity of training of both clinicians and radiologists.

Keywords: Neonate; Imaging Investigation Costs; Radio-Imaging Pathological Findings; Clinical-Imaging Concordance.

Introduction

The quality improvement in health care systems is one of the major aims in medical care reform all over the world [1-4]. The basic approaches are represented by structural reorganisation [5], system reform [6-10] and development of appropriate organizational culture [11].

The preoccupation with cost shifting and cost reduction undermines physicians and patients in Romania [12,13]. The Romanian health care system has been "in reform" since 1989, shifting from an integrated, centralized, state-owned and state-controlled tax-based system to a decentralized, social health insurance model that is still underway [14-16].

On a decreasing annual population growth rate, a fertility rate under population replacement and on an increase in the population age over 60 years in the last decade [17], the infant mortality in Romania is among the highest in the European Region (perinatal mortality rate of 12 [18]). An early

diagnostic of neonatal pathology is a main aim of modern medicine because it allows a more efficient treatment of the newborn. The newborn receives a special attention due to the age and its particularities, to the risks and specific pathology of this age group.

The present research aimed to investigate the trend of costs for imaging techniques (costs evolution and cost per patient) used as diagnostic tools (abdominal and transfontanelar ultrasonography, computer tomography, magnetic resonance and radiography) for cerebral and abdominal neonatal pathology and to study the relationship between cost and diagnostic benefit.

Material and Method

Newborn Patients

A retrospective observational study was conducted for investigation of five imaging diagnostic techniques used in the diagnosis of cerebral and abdominal neonatal pathology: abdominal and cerebral ultrasonography, conventional radiography, computer tomography and magnetic resonance imaging. The study population was represented by neonates (begins with birth and ends 30 complete days after birth), born at Gynaecological Clinic No. 1, Cluj District University Hospital and sent for imaging investigation to the Radio-Imaging Department for abdominal and/or cerebral pathology. All investigations performed since October 2000 to February 2006 were included into the study.

The following criteria were used for inclusion into the study: clinical susceptibility of abdominal or cerebral pathology; recommendation of an imaging investigation for diagnosis or follow-up addressed to Radio-Imaging Department, age less than or equal with 30 days. There were excluded from the study: the newborns antepartum diagnosed with abdominal and/or cerebral pathologies, the newborns with a health status that did not allow transportation from Neonathology Department to Radio-Imaging Department, the newborns whose pathology suspicion did not have indication for imaging investigation and the newborns whose parents refused radio-imaging investigation.

Partial Economic Analysis

The cost of imaging investigation comprised direct costs (costs determined by the provided service) and indirect costs (costs associated with the provided service). The cost components and associated values according with the type of examination are summarized in Table 1.

Table 1. Direct and Indirect Costs of Imaging Investigations

	Direct costs		***Indirect costs***			
	Staff	**Materials**	**Amortization**	**Sustenance**	**Spare parts**	**Stage direction**
US	6h/day 20 min/exam 25 exams/day	Videoprinter paper (6 img/exam) Ecogel	Device 40000€* Videoprinter 9000€	5% DP	2000€ / year	25% TCE
CT	6h/day 30 min/exam 24 exams/day	Radiographic films CD-Rom	Device 500000€+ Developer device 10000€**	10% DP	15% DP / year	25% TCE
MRI	6h/day 40 min/exam 18 exams/day	Radiographic films CD-Rom	Device 1000000€* Developer device 10000€**	8% DP	15% DP / year	25% TCE
CR	6h/day 10 min/exam 40 exams/day	Radiographic films CD-Rom	Device 200000€* Developer device 10000€**	5% DP	7.5% DP / year	25% TCE

US = ultrasonography; CT = Computer Tomography; MRI = Magnetic Resonance Imaging; CR = conventional radiography; DP = device price; exam = examination; TCE = total cost of examination; img = images

* Average utilization time = 5 years;

** Average utilization time = 10 years;

Data Analysis

The data analysis consisted of the description of the cost components for the radio-imaging investigations included, the analysis of cost evolution in the period studied and the description of the cost-result relation. The Statistics 6.0 software has been used for data summarizing and analysis. The graphic representations were realized with Microsoft Excel.

Results

One hundred and seventy newborns with cerebral or abdominal pathology accomplished the inclusion and exclusion criteria. Fifty-seven percent (95%CI [49.41-64.70]) were boys.

The age of the patients included was between 1 day and 30 days, with an average of 20.13 days (95%CI [18.64-21.62]). Absolute frequency distribution by age classes is shown in Figure 1.

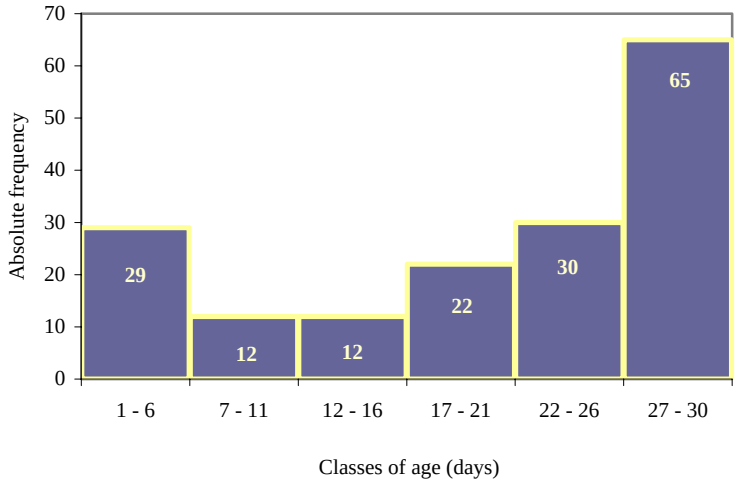

Figure 1. Distribution of age on frequency classes

One hundred and eight patients (63.53%, 95%CI [55.88 – 70.58]) were investigated for a cerebral pathology and 62 patients (36.47%, 95%CI [29.44 – 44.11]) for an abdominal pathology.

The distribution of the investigation type related to the number of patients and the year when the investigation was performed is presented in Table 2.

Table 2. Radio-imaging investigations: October 2000 – February 2006

Investigation	Patients/Year							Total
	2000	2001	2002	2003	2004	2005	2006	
Computer tomography	0	0	10	7	27	6	4	***54***
Abdominal ultrasonography	1	4	6	7	14	15	0	***47***
Abdominal ultrasonography + Computer tomography	0	0	0	0	0	1	0	***1***
Abdominal ultrasonography + Transfontanelar ultrasonography	1	0	3	0	4	7	0	***15***
Abdominal ultrasonography + Radiography	0	0	0	0	0	1	0	***1***
Transfontanelar ultrasonography	1	8	10	6	4	4	0	***33***
Transfontanelar ultrasonography + Computer tomography	0	0	2	1	1	0	0	***4***
Transfontanelar ultrasonography + Magnetic Resonance	0	0	0	0	0	1	0	***1***
Radiography	0	0	0	2	2	1	0	***5***
Magnetic Resonance	0	1	1	0	0	7	0	***9***
Total	***3***	***13***	***32***	***23***	***52***	***43***	***4***	**170**

The distribution of the number of investigations related to the year when the investigation was performed is presented in Table 3.

Table 3. Distribution of the number of investigations per year: October 2000 – February 2006

Investigation	Year							Total
	2000	2001	2002	2003	2004	2005	2006	
Abdominal ultrasonography	2	4	14	8	20	24	0	***72***
Transfontanelar ultrasonography	1	8	15	7	9	12	0	***52***
Computer tomography	0	0	15	8	38	7	4	***72***
Magnetic Resonance	0	1	1	0	0	9	0	***11***
Radiography	0	0	0	2	2	2	0	***6***
Total	***3***	***13***	***45***	***25***	***69***	***54***	***4***	**213**

The costs evolution of radio-imaging investigation on years and investigation types during 2000-2006 is presented in Figure 2.

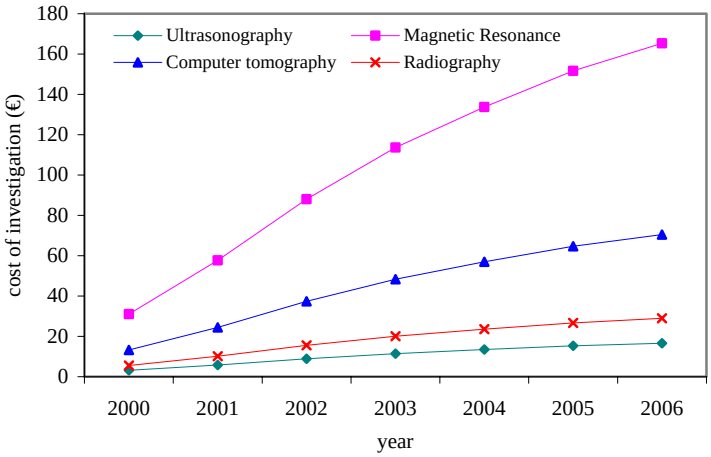

Figure 2. Cost evolution during 2000 - 2006

The percentage of the yearly cost raise is presented in Table 4.

Table 4. Percentage of cost raise

Investigation	2001/2000 (%)	2002/2001 (%)	2003/2002 (%)	2004/2003 (%)	2005/2004 (%)	2006/2005 (%)
Ultrasonography	84.21	52.86	28.97	18.12	13.50	8.11
Magnetic Resonance	86.00	52.69	29.11	17.64	13.45	8.99
Computer tomography	84.38	52.88	29.16	18.03	13.45	8.97
Radiography	83.58	52.85	28.99	17.53	13.16	8.53

The number of investigations related with the investigation type is presented in Figure 3.

Total costs per type of investigation on years, expressed in Euro, are presented in Table 5.

Pathological radio-imaging modifications were observed in 124 out of 213 investigations (58.2%, 95%CI [47.19 - 60.17], see Table 6).

From 170 patients, pathological radio-imaging modifications were observed in 98 patients (57.64% 95%CI [50.00 – 65.29]), as it can be seen in Table 7.

The cost distribution related to the year when the investigation was performed and the radio-imaging findings, expressed in Euro, is presented in Table 8.

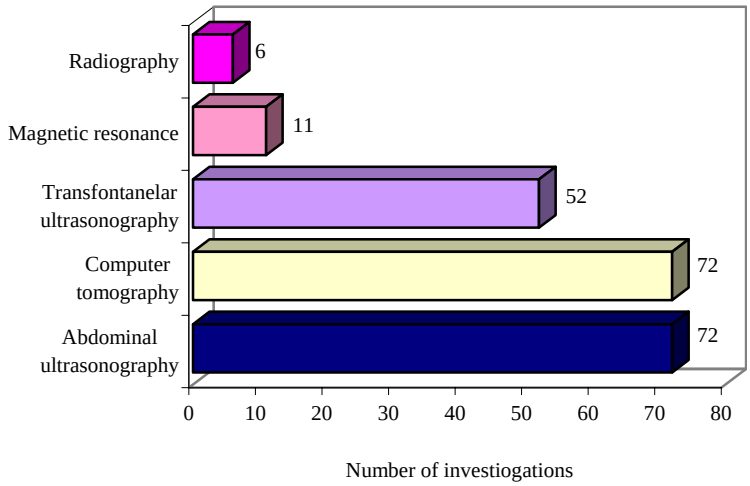

Figure 3. Number of investigations during October 2000 – February 2006

Table 5. Total costs of radio-imaging investigations: 2000-2006 (€)

Investigation	Year							Total
	2000	2001	2002	2003	2004	2005	2006	
Abdominal Ultrasonography	6.30	23.20	53.16	80.01	202.50	229.80	n.a.	594.97
Abdominal Ultrasonography + Computer Tomography	n.a.	n.a.	n.a.	n.a.	n.a.	79.99	n.a.	79.99
Abdominal + Transfontanelar Ultrasonography	n.a.	n.a.	97.46	22.86	135.00	214.48	n.a.	469.8
Abdominal Ultrasonography + Radiography	n.a.	n.a.	n.a.	n.a.	n.a.	42.02	n.a.	42.02
Transfontanelar Ultrasonography	3.15	46.40	88.60	57.15	40.50	61.28	n.a.	297.08
Transfontanelar Ultrasonography + Computer Tomography	n.a.	n.a.	92.52	59.73	127.5	n.a.	n.a.	279.75
Transfontanelar ultrasonography + Magnetic Resonance	n.a.	n.a.	n.a.	n.a.	n.a.	318.72	n.a.	318.72
Radiography	n.a.	n.a.	n.a.	40.16	47.20	26.70	n.a.	114.06
Magnetic Resonance	n.a.	57.66	88.04	n.a.	n.a.	1061.90	n.a.	1207.6
Computer Tomography	n.a.	n.a.	486.20	338.10	2052.00	388.02	281.88	3546.2
Total	***9.45***	***127.26***	***905.98***	***598.01***	***2604.7***	***2422.91***	***281.88***	**6950.19**

n.a. = not applicable

Table 6. Number of radio-imaging investigations: normal versus pathological findings

Investigation	Radio-imaging findings		Total
	Normal	Pathological	
Abdominal Ultrasonography	32	40	72
Transfontanelar Ultrasonography	31	21	52
Computer Tomography	21	51	72
Magnetic Resonance	5	6	11
Radiography	0	6	6
Total	***89***	***124***	***213***

The average cost of imaging investigations for patients with identified pathologic aspects was € 42.72 while for patients with no pathologic imaging aspects was € 37.62. To test the hypothesis that there are or not significant differences between these costs, the Mann-Whitney test was applied. There were 98 cases (57.64%) in which pathology has been identified at the imaging investigation and 72 cases (42.36%) without pathological modifications. The Z parameter had a value of 1.63 and an associated probability of 0.10.

Table 7. Number of patients with normal versus pathological radio-imaging findings on years

Year	Radio-imaging findings		Number of patients
	Normal	Pathological	
2000	1	2	3
2001	9	4	13
2002	18	14	32
2003	5	18	23
2004	24	28	52
2005	14	29	43
2006	1	3	4
Total	***72***	***98***	***170***

The concordance between the clinical suspicion and the radio-imaging diagnosis was observed in 52.35% (95%CI [44.71 - 59.99]), while the absence of concordance was of 47.64% (95%CI [40.00 – 55.29]) as it is presented in Table 9.

Table 8. Radio-imaging investigation costs related with year, investigation type and radio-imaging findings (€)

Investigation type	Normal vs pathologic	2000	2001	2002	2003	2004	2005	2006	Total
Abd US	normal	3.15	17.40	53.16	n.a.	148.50	168.52	n.a.	390.73
	pathologic	3.15	5.80	70.88	91.44	121.50	199.16	n.a.	491.93
Total Abs US		***6.30***	***23.20***	***124.04***	***91.44***	***270.00***	***367.68***	***0.00***	***882.66***
TF US	normal	n.a.	34.80	97.46	45.72	108.00	30.64	n.a.	316.62
	pathologic	3.15	11.60	35.44	34.29	13.50	153.20	n.a.	251.18
Total TF US		***3.15***	***46.40***	***132.90***	***80.01***	***121.50***	***183.84***	***0.00***	***567.80***
CCT	normal	n.a.	n.a.	112.20	96.60	627.00	323.35	70.47	1229.62
	pathologic	n.a.	n.a.	448.80	289.80	1539.00	129.34	211.41	2618.35
Total CCT		***0.00***	***0.00***	***561.00***	***386.40***	***2166.00***	***452.69***	***281.88***	***3847.97***
MR	normal	n.a.	0	88.04	n.a.	n.a.	606.80	n.a.	694.84
	pathologic	n.a.	57.66	0	n.a.	n.a.	758.50	n.a.	816.16
Total MR		***0.00***	***57.66***	***88.04***	***0.00***	***0.00***	***1365.30***	***0.00***	***1511.00***
Rgr	normal	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.00
	pathologic	n.a.	n.a.	n.a.	40.16	47.20	53.40	n.a.	140.76
Total Rgr		***0.00***	***0.00***	***0.00***	***40.16***	***47.20***	***53.40***	***0.00***	***140.76***
Total	normal	3.15	52.20	350.86	142.32	883.50	1129.31	70.47	2631.81
	pathologic	6.30	75.06	555.12	455.69	1721.20	1293.60	211.41	4318.38
Sum		***9.45***	***127.26***	***905.98***	***598.01***	***2604.70***	***2422.91***	***281.88***	***6950.19***

Abd US = abdominal ultrasonography; TF US = transfontanelar ultrasonography
CCT = cerebral computed tomography; MR = magnetic resonance
Rgr = radiography; n.a. = not applicable

Table 9. Clinical-imaging concordance: number of patients on years

Year	Clinical-imaging concordance		Number of patients
	Yes	No	
2000	2	1	3
2001	4	9	13
2002	12	20	32
2003	15	8	23
2004	27	25	52
2005	26	17	43
2006	3	1	4
Total	***89***	***81***	***170***

The cost distribution related to the year when the investigation was performed and the clinical-imaging concordance is presented in Table 10.

The average cost of imaging investigations for patients with clinical-imaging concordance was € 42.87, and for patients without concordance was € 37.02 (see Table 10). To test the hypothesis that there are or not significant differences between the imaging investigation costs for patients with and without clinical-imaging concordance, the Mann-Whitney test was applied. A concordance between clinical and imaging diagnostic has been identified in 89 patients. A value for the Z parameter of 2.87 (p = 0.0041) has been obtained.

Table 10. Radio-imaging investigation costs related with year, investigation type and clinical-imaging concordance (€)

Investigation type	Clinical-Imaging Concordance	2000	2001	2002	2003	2004	2005	2006	Total
Abd US	yes	3.15	11.60	70.88	80.01	108.00	260.44	n.a.	534.08
	no	3.15	17.40	53.16	11.43	162.00	107.24	n.a.	354.38
Total Abs US		***6.30***	***29.00***	***124.04***	***91.44***	***207.00***	***367.68***	***0.00***	***882.66***
TF US	yes	3.15	5.80	35.44	34.29	27.00	122.56	n.a.	228.24
	no	n.a.	34.80	97.46	45.72	94.50	61.28	n.a.	333.76
Total TF US		***3.15***	***40.60***	***132.90***	***80.01***	***121.50***	***183.84***	***0***	***562.00***
CCT	yes	n.a.	n.a.	374.00	193.20	1539.00	129.34	211.41	2446.95
	no	n.a.	n.a.	187.00	193.20	627.00	323.35	70.47	1401.02
Total CCT		***0.00***	***0.00***	***561.00***	***386.40***	***2166.00***	***452.69***	***281.88***	***3847.97***
MR	yes	n.a.	57.66	n.a.	n.a.	n.a.	455.10	n.a.	512.76
	no	n.a.	n.a.	n.a.	n.a.	n.a.	910.20	n.a.	910.20
Total MR		***0.00***	***57.66***	***0.00***	***0.00***	***0.00***	***1365.30***	***0.00***	***1422.96***
Rgr	yes	n.a.	n.a.	n.a.	40.16	47.20	53.40	n.a.	140.76
	no	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.00
Total Rgr		***0.00***	***0.00***	***0.00***	***40.16***	***47.20***	***53.40***	***0.00***	***140.76***
Total	yes	6.30	75.06	480.32	347.66	1674.00	1020.84	211.41	3815.59
	no	3.15	52.20	337.62	250.35	883.50	1402.07	70.47	2999.36
sum		***9.45***	***127.26***	***817.94***	***598.01***	***2557.50***	***2422.91***	***281.88***	***6814.95***

Abd US = abdominal ultrasonography; TF US = transfontanelar ultrasonography;
CCT = cerebral computed tomography; MR = magnetic resonance; Rgr = radiography; n.a. = not applicable

Discussion

The studied sample was too heterogeneous to be appropriate for definitive statistic analysis but, even under those circumstances, the study brings interesting and concrete information, on a long period and can be a basis for further research.

The costs for radio-imaging investigations were calculated based on the regulations applied in the Romanian public health care institutions. This modality of covering costs is considerably different comparing to other countries, where "performance" criteria are used [19-21][, ,]. So, from this point of view, there cannot be done comparisons.

Without claiming to realize an ideal cost that would reflect all the expenses incurred by an investigation, it can be considered that the summation of the elements considered is a significant appreciation, of about 85%, of the imaging investigation costs in the District University Hospital Cluj. Even if not ideal, using the same element costs over the studied years makes possible a cost analysis and its relation with the clinical results.

Cost Analysis

Under the perspective of total costs on investigation type, magnetic resonance is the most expensive investigation, followed by computer tomography, conventional radiology and ultrasonography (see Figure 2).

The costs of abdominal and transfontanelar ultrasonography were similar, because there are no significant differences between the direct and indirect costs for these investigations. Conventional radiology is about two times more expensive, computer tomography is about four times more

expensive and magnetic resonance is about ten times more expensive, if ultrasonography is taken as reference investigation (the less expensive investigation).

Cost Evolution

Under the perspective of cost evolution during 2000 – 2006 (see Table 4), two main remarks can be done: the rate between the raising of costs on investigation type on year is constant, and the raise of radio-imaging investigation costs had a descending tendency, from an important raise, of about 85% in 2001 compared to 2000, to a raise of about 8.5% in 2006 compared to 2005. This phenomenon might be explained by the stabilization of the Romanian monetary market, correlated with the stabilization of the reimbursement mechanisms in the health care social insurance system.

The biggest cost raise during 2000 – 2006 was registered for magnetic resonance (see Figure 2), the raise being due both to direct and indirect investigation costs. The direct costs raised due to the raise of the number of investigations performed at clinicians' request, but also by the increase of personnel and specific materials costs. The raise of the investigation number is the consequence of a larger accessibility for this high performance investigation, but also of an enlarging clinical indication frame.

The smallest cost raise percentage during 2000 – 2006 is registered for ultrasonography (see Figure 2), this being explained, at least for the studied sample, by relatively constant direct and indirect costs.

The interpretation of total costs evolution over years (see Figure 2) is difficult to be done due to the heterogeneously studied sample. It can be observed a cost raise in 2005 and 2004, compared to 2000 – 2003 (a raise of about four times in 2004 comparative to 2003), explained both by the cost raise of an investigation and the raise of the number of investigations. For 2006, in the graphic representation was considered the investigation cost, resulted from cost calculation, but there cannot be done appreciations about the relation with the number of investigations, because the studied period was of only two months.

Results Analysis

During October 2000 and February 2006, a number of 170 neonates were radio-imaging investigated, with an average age of 20,13 days, observing a higher number of clinical indications in days 0-6 (29 patients) and in days 22-30 of life (95 patients) (see Figure 1). This distribution is correlated with the distribution of cerebral and abdominal pathology diagnosed at these age groups.

The distribution of investigation type (see Figure 3) showed the following:

- A high rate of ultrasonography investigations (58.21%), which is correlated both with the clinical indication and with the accessibility and its innocuity.
- Under the specific hospital conditions, the high rate of computer tomography investigations (33.82%) compared to magnetic resonance investigations (5.16%) is firstly due to the accessibility to high performance equipments in the studied period.
- The principle of justification an ionizing investigation was applied for conventional radiology investigations, which can be related to the reduced number of patients addressed for this type of investigations (2.81%) and also by the fact that there had not been any indication for radiological investigations for cerebral pathology, which is correlated with the diagnostic utility of this method of investigation.

Cost Result Analysis

In 58.2% of the investigated cases were identified pathological modifications (see Table 6) while the percentage of the patients in which pathological modifications were diagnosed was of 57.6.% (see Table 7).

From the investigation costs point of view, there could not be identified a significant difference between the average cost on patients with and without imaging pathological modifications ($p = 0.10$) even if the cost of the investigation was almost two times higher for patients with pathological imaging modifications compared with the patients without pathological imaging modification. Translating into economical terms, this means that there have been spent as much money for useful

imaging investigations as for investigations where the imaging examinations did not show any diagnostic benefit. This is contrary to expectations, which presume that the costs of beneficial investigations should be significantly higher than the costs of investigations that reveal the absence of the suspected pathology. This result can be explained both by an abusive use of indications made by the clinicians and by a lack of training for the radiologist.

A concordance between the clinical suspicion and the radio-imaging diagnosis was observed for 52.4.% of patients (see Table 9), which means, clinically translated, that only for half of the cases addressed the initial diagnosis was confirmed.

The analysis of the average investigation cost for patients with (€42.87) and without (€37.02) clinical-imaging concordance identified significantly higher costs for patients with compared with patients without clinical-imaging concordance ($p < 0.01$).

Taking into consideration the fact that there are no significant statistical differences between the age of the patients addressed and the investigations cost, and considering the sample studied, there cannot be driven final conclusions over "redundancies" of indication or over the utility or the benefit of radio-imaging investigation for the patients addressed. The percentage of identification of pathological alterations, of about 57.6%, is encouraging from a medical point of view. The percentage of clinical-imaging concordance, of about 52.4%, can stimulate further analysis regarding the need for training in the specific neonatal pathology, the indications of radio-imaging investigations in this area of pathology diagnosis and also the need for a more efficient communication between the clinician and the radiologist.

Conclusions

In Romania, today, there are no sufficient data to prove or disprove the utility of radio-imaging investigations in the diagnosis of neonatal cerebral and abdominal pathology.

The raise of radio-imaging investigation costs had a decreasing tendency over the years studied, which can be explained by the stabilization of the Romanian monetary market correlated with a stabilization of the reimbursement mechanisms in the Romanian health care insurance system.

The average imaging investigation costs for patients with pathological findings was higher compared with costs for patients without pathological findings, but the difference was not statistically significant ($p > 0.05$). Nevertheless, a statistically significant difference between the imaging investigation costs for patients with and without clinical-imaging concordance, in favour of the first category, had been observed.

The results of the study revealed the need of a better communication between the clinician and the radiologist, and the necessity of continuing medical education programs both for the clinician and the radiologist.

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