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DEMOGRAPHIC CHANGES IN BRAIN CT AND MR IMAGING BETWEEN 1990 AND 2010

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Study objective: **During the last decades, computed tomography and magnetic resonance imaging have revolutionized neuro-imaging. Nowadays these techniques are routinely used, but the extent and variation of use has been investigated poorly. Our purposes were to retrospectively determine the evolution in demographic variables and indications of cranial CT and MRI scanning in 1993, 2000 and 2009, at our hospital.**
Methods: **We retrospectively studied medical and neurologic in- and outpatients, who underwent CT- or MR imaging of the head for several demographic and patient characteristics.**
Results: **We observed a modest increase in mean age and a marked increase in total number of cranial CT examinations, MR confirmation studies and repeat examinations. Metastatic disease, head injury and headache were indications associated with more rapid growth in CT use than were others.**
Conclusion: **Among the 5 patient and hospital factors considered (total number of examinations, age, indication, MR confirmation study and repeat examinations), all had a significant variation during the past 16 years. Strict regulations with compelling guidelines for the rational use of brain CT and MRI are inevitable in order to control expenditure and radiation exposure.**

Key-words: Brain, CT – Brain, MR - Epidemiology.

Radiological imaging was and still is a fast growing sector of health care industry. Neuro-imaging has experienced major and significant changes, this in almost exclusively high-cost imaging modalities like computed tomography (CT) and magnetic resonance (MR) imaging (1). Since these imaging modalities have proven themselves sensitive in appropriate applications, they have become essential tools in evaluating several neurological conditions (2). Despite these developments, use patterns of these procedures remain unknown. We determined in this study the extent of use and trends for CT and MR imaging in our hospital, as well as possible reasons for the changes, by comparing the use rates of neuro-imaging procedures performed in 1993, 2000 and 2009.

Materials and methods

Study population

Our study population consisted of medical and neurologic in- and outpatients, who underwent brain CT or MR imaging at our hospital, in order to maximize the generalization of our results.

Data collection and processing

Data were retrospectively collected from a database of all radiology examinations at our institution. Automated classification of radiology reports identified 2214 head computed tomographic and 1486 brain magnetic resonance imaging examinations, performed during a one-month period (October) in 1993, 2000 and 2009.

Finalized radiology reports in our radiology information system (RIS) are archived by patient medical record number and examination accession number in the database (PACS System). Not all examinations that were performed during the study period were included. For example, patients undergoing CT-scanning more than once in the defined study period were excluded. After this exclusion for each year, a study cohort of 2159 cranial CT examinations remained. First, data were subcategorized according to age, into eleven age groups, each of ten years. Second, patients were classified according to clinical information and radiological questioning. Here we only used those patients who underwent cranial CT scanning during the first two weeks of October, supposing this would be a representative study population. Seizure was defined as a suspected or witnessed seizure. Bleeding was defined as control of known intracranial hemorrhage. Metastasis was defined as screening for this malignancy. Headache was defined as any head pain, whether diffuse or local. Head injury was defined as any trauma above the clavicles, including contusions, abrasions, lacerations and deformities. Third, we determined repeat examination rate, which is defined as a CT examination performed in a patient, who did have a previous CT scan/MR scan for the same indication, in the period of 1 month before the actual study. This specific time interval was chosen in trying to exclude examinations performed for another episode of illness or for annual screening. Finally we considered patients who underwent additional MRI study of the head, within 20 days after the CT scan was performed. Results were subdivided into MRI studies at less than 48 hours, between 2 and 5 days, between 5 and 10 days, and between 10 and 20 days. These four time intervals were chosen to approximate various patient care episodes. Zero to forty-eight hours encompasses emergency department care and 20 days encompasses most hospital admissions.

Methodology

A MEDLINE search of English language publications was conducted for the period from January 1990 through February 2011 using the following medical subject heading (MeSH) search terms: tomography, x-ray computed, head, epidemiology and magnetic resonance imaging. These terms were searched in all fields of publication.

Results

During the last 16 years significant variation was found among most of

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Table I. — Absolute number of CT studies and previous cranial CT and MR examinations for the 9 most common cranial CT indications in 1993, 2000 and 2009.

	1993			2000			2009		
Indication	Total No. of CT studies*	CT study before**	MRI study before***	Total No. of CT studies*	CT study before**	MRI study before***	Total No. of CT studies*	CT study before**	MRI study before***
Stroke	37	6	4	58	4	3	73	2	2
Post operative	35	23	16	34	15	7	49	36	30
Head injury	25	1	0	26	1	0	67	3	1
Headache	20	0	0	33	1	0	44	12	2
Bleeding	19	12	3	18	10	0	34	23	6
Mental deterioration	17	2	4	22	3	1	32	6	1
Dizziness	12	0	0	10	1	0	11	0	0
Seizure	12	3	2	16	3	1	17	10	4
Metastasis	11	3	0	29	6	4	36	10	5
Total:	188	50	29	246	44	16	363	102	51

*Absolute number of CT-examinations performed during the first two weeks of October.
**Number of patients, with previous cranial CT study(-ies), performed in September.
***Number of patients, with previous cranial MRI study(-ies), performed in September.

the 5 patient and hospital factors considered in our study.

Frequency

From 1993 to 2009, the number of CT examinations increased from 491 to 1041, constituting a 2-fold increase. When compared to the 1993 data, the incidence rate in 2000 had increased by 41%.

Indication

The 10 most commonly asked radiological questions/clinical information associated with CT scanning were identified for each year, and listed in Table I. During the 16-year period studied, stroke was the most common indication. The absolute number of CT investigations increased substantially for all questions during the survey period. Still, metastatic disease (3.3 times more investigations), head injury (2.7 times higher) and headache (2.2 times higher) were indications associated with more rapid growth in CT use than were others.

Repeat examinations

Repeat examinations account for nearly 20% of total number of CT examinations in 1993, 12% in 2000 and 20% in 2009, representing a constant proportion (Table I). Patients with known intracranial hemorrhage and those who had undergone cranial surgery comprise the major group of commonly repeated examinations. Taken together, they account for more than 70%, 57% and 57% of the CT repeat examinations in 1993, 2000 and 2009 respectively.

Age

The mean age of the 2159 patients studied, increased from 45 years in 1993, to 53 years in 2000 (+ 20%) and 57 years in 2009 (+26%). As shown in Fig. 1, the number of patients undergoing cranial CT scanning varied by age.

MR confirmation

In October 1993, 280 cranial MR scans were performed in our hospital. In 2000 and 2009, the use rate of brain MR was 515 and 691 procedures respectively. This change represents a 247% increase in the use rate of MR neuro-imaging procedures in our study population in 2009 compared with 1993.

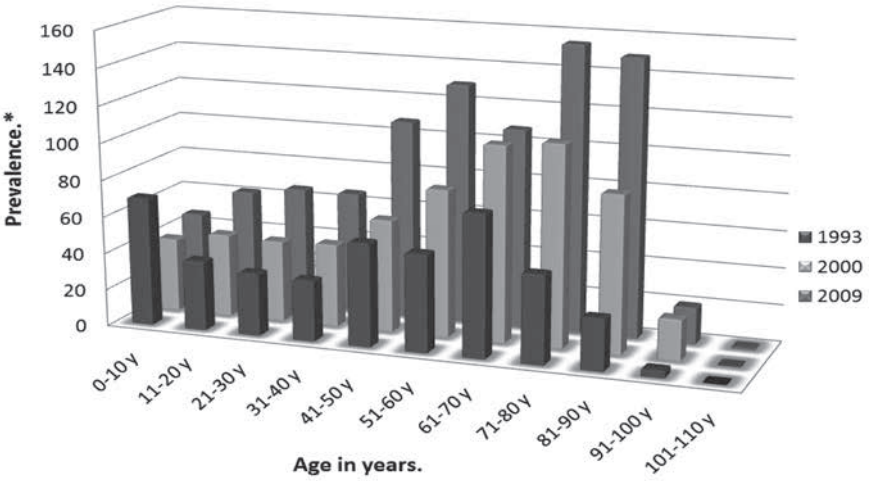
From 1993 to 2009, the number of MR-confirmation studies increased from 13 to 82, constituting a 6.3-fold increase (Table II). Less than 10 percent of patients had confirmation with MR scanning of the head (3% in 1993, 7% in 2000 and 8% in 2009). Of these, stroke and seizure have been associated with the most MR-confirmation studies.

Limitations

Some limitations of the study need to be considered. A first limitation is that our study suffers from a lack of generalization, because it relies on data from a single institution. We could be under- or overestimating, as examinations performed outside our institution would not have been captured. Secondly, our retrospective data are influenced by non-medical factors, i.e. governmental policy in limiting the total number of MRI units. Finally, we included no information on the diagnosis. Therefore, it was impossible to compare changes in use for different diagnostic groups.

Discussion

In the first years after the introduction of computed tomography (CT) in 1972, the technique was a scarce resource reserved for severely disabled patients. As CT scanners became more widely available, they were seen as an accurate method in diagnosing structural brain diseases. Even after the discovery of magnetic



*Prevalence in absolute number of CT examinations for each age group.

Fig. 1. — Distribution pattern of cranial CT examinations, according to patient's age

resonance imaging in the late 1980s, CT remained the investigation method for the diagnosis and management of many central nervous system diseases (2).

Frequency

Our study revealed a doubling in total number of cranial CT examinations, between 1993 and 2009. In Belgium, between 2000 and 2007, the number of CT examinations grew up to 51.44% (3). This increased CT utilization was expected. But surprising is the sustained high rate of this growth. The increase is influenced by population aging, upgrading imaging modalities, expanding knowledge throughout the medical community about the capabilities of CT in the study of neurologic disorders, the patient expectations, increasing availability of CT scanners, the national health care planning policies

Table II. — Time interval between CT examination and MR confirmation.

	Indication	Total No. of CT -examinations	< 48h*	2-5d*	5-10d*	10-20d*	
1993	Stroke	37	0	2	2	1	
	Seizure	12	2	1	1	1	
	Postoperative control	35	2	0	1	0	
			4	3	4	2	*Total:* 13
2000	Stroke	58	7	8	11	2	
	Seizure	16	2	1	1	1	
	Metastasis	29	1	0	1	0	
	Head injury	26	1	0	0	0	
	Postoperative control	34	0	0	2	0	
	Headache	33	1	0	1	0	
	Dizziness	10	1	2	2	0	
	Mental deterioration	22	0	0	2	0	
			13	11	20	3	*Total:* 47
2009	Stroke	73	27	7	3	4	
	Seizure	17	2	4	0	1	
	Metastasis	36	3	2	0	4	
	Head injury	67	1	0	3	1	
	Postoperative control	49	1	1	1	5	
	Headache	44	0	1	4	2	
	Dizziness	11	2	1	0	0	
	Mental deterioration	32	0	1	0	1	
			36	17	11	18	*Total:* 82

*Number of examinations confirmed by MR scanning in the indicated period (h = hours/d = days).

and also some physicians are still not willing to accept the risk of missing an abnormality (1) (4-5). Also the contribution of radiologist self referral has repeatedly come under scrutiny. Lee et al. were able to counter this hypothesis in their study published in 2007 (6). In contrast, limiting factors include caution regarding to radiation and interventions to improve evidence-based guideline adherence (7). This rapid increase is a measure of the increasing power of radiology in medical care, but even so a measure for the radiology workload, since the number of radiologists is not increasing at the same pace. Possible solutions can be found in technologic advances. The increasing use of CT has also become a subject of concern for national health authorities. In 2000, Belgian expenditures on CT and MR examinations were 122 million euro (this is 14% of the total expenditures on medical imaging). In 2009, these expenditures increased to 214 million euro, representing 19% of the total expenditures on medical imaging (3).

Indication

In our study, stroke was the indication most commonly associated with cranial CT scanning. Computed tomography still plays a central role in the evaluation of patients with acute cerebral ischemia. It is used to differentiate ischemic from hemorrhagic stroke and even may demonstrate evidence of early ischemic changes (8). According to our findings, head injury was commonly associated to the use of CT and remained essentially stable during the study period. Cranial CT scanning is considered to be the imaging modality of choice for the rapid and reliable diagnosis of traumatic head injuries (9). Several retrospective studies conclude that CT is indicated in all patients with minor head injury (10-11). Finally, headache was a frequently asked radiological question. A study by Frischberg et al. has shown that headache, is one of the most common complaints encountered by general practitioners and neurologists (12). Neuro-imaging is in most of cases not indicated (13). Still, in our study it was listed as one of the most frequently asked questions associated with CT scanning.

Repeat examinations

As expected, a modest percentage of patients had undergone previous neurologic imaging. Patients who had undergone cranial surgery comprise the major group of commonly repeated examinations. This reflects the reliance on cross-sectional imaging in surgery follow-up. Another reason performing repeat imaging is the economic pressure within the health care system. An American analysis of inpatient hospital costs demonstrated that, for every $100 spent on diagnostic imaging, hospitalization was reduced by about 6 hours (14).

Age

Our finding is that CT was and still is more frequently used in middle aged and elderly. This is similar to the findings of other authors (15-16). Still, we found a relatively high rate and alarming growth in CT use among children and adults, knowing that this age group is more vulnerable to harmful effects of radiation. We suggest further investigation to confirm this finding, as we do not have enough information to identify the causing mechanisms.

MR-confirmation

MR scanning is especially helpful for patients in whom the CT examination revealed an abnormality that cannot sufficiently be characterized. The complementary roles of CT and MRI offer a powerful tool for the diagnosis and management of benign and malignant conditions. According to our findings, MRI may have a greater role in the evaluation, as it becomes more widely available. MRI is superior to CT but the cost of MRI remains higher (17). Therefore it is important to avoid the simultaneous use of both techniques and to encourage the substitution of CT by MR imaging. In contrast with CT, the total number of MRI units in Belgium is restricted and determined by government. Besides accredited MRI units, a number of non-accredited units are operational in Belgium. These are not entitled to the reimbursement of MRI services, but need to be taken into account, in order to have a complete view on all operational units. Though, data on the non-accredited units is not easy to obtain, therefore estimates were made. In 2000 the number of accredited and estimated non-accredited MRI units in Belgium was 59, in 2008 the total number of MR units was 96. As there is no data available of 1993, the total number was estimated on 9 units (3, 18). Still, our study was not aimed at measuring under- or overuse of this imaging technique.

Conclusion

In summary, we found substantial temporal changes in almost all of the patient and hospital factors from 1993 through 2009. There is a paucity of literature that discusses epidemiologic information about utilization of radiology services. Still they can elucidate future needs and help to ensure that necessary services are available for patients. These studies are not only important for radiologists in making financial decisions and evaluating their hospital practice, they are of great value for policy makers and health insurance parties as these techniques are quite expensive. A more rational use of brain CT and MRI examinations enforced by guidelines seems inevitable in the near future in order to control expenditures as well as radiation exposure to patients.

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