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IAEA QUATRO audits in Europe

Improving the quality of radiation oncology: 10 years' experience of QUATRO audits in the IAEA Europe Region

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ABSTRACT

Background and purpose: The IAEA has developed a methodology for comprehensive quality audits of radiotherapy practices called Quality Assurance Team for Radiation Oncology (QUATRO). This study explores the factors that impacted quality of care among QUATRO audited centres in the IAEA Europe Region.

Materials and methods: The 31 QUATRO reports collected over 10 years include extensive data describing the quality of radiotherapy at the audited centres. A coding key was developed to aggregate and review these data in terms of recommendations for improvement and positive findings (commendations).

Results: Overall 759 recommendations and 600 commendations were given. Eight centres recognized as centres of competence differed from other centres mostly because they operated complete quality management systems and were adequately staffed. Other centres had excessive staff workloads and many gaps in the process of care. Insufficient equipment levels were prevalent. Patient centredness, communication, dosimetry, quality control and radiation protection were frequently commended by QUATRO.

Conclusions: This analysis points to barriers to quality care such as insufficient staffing, education/training, equipment and lack of quality management. It highlights the correlation between the human resources availability and quality of care. It has also identified common action items for enhancing quality of radiotherapy programmes in the Region.

The Global Task Force on Radiotherapy for Cancer Control has recently published its report highlighting the shortage of radiotherapy treatment facilities worldwide [1]. While establishing capacity has to be the first priority, the quality of the service provided by radiotherapy programmes is the major determinant of outcome for patients.

Although a universally accepted, specific definition of quality in radiotherapy is lacking, the provision of quality treatment is the aspiration of the radiotherapy community [2–4]. Assuring the quality of radiotherapy treatment is largely carried out within the clinical programme itself. However, there is considerable value in including an independent, external review as a component of quality management programmes [5–7].

The IAEA has contributed to the quality of radiotherapy worldwide since 1969 when the IAEA/WHO postal dosimetry audit was introduced [8]. While accurate radiation dosimetry is a necessary condition for quality radiotherapy it is not, of itself, a sufficient condition. Degradation of quality can clearly enter the radiotherapy care path in many places besides machine calibration. Given the IAEA experience in dosimetry auditing over many years, requests were received to conduct audits of clinical practices. In response, the IAEA developed the Quality Assurance Team for Radiation Oncology (QUATRO) audit methodology [9] which has been endorsed by professional societies and recognized by the European Commission in its guidelines for clinical audits [10].

To date 89 IAEA QUATRO audits have been conducted in 77 radiotherapy centres in Europe, Asia, Africa and Latin America. The QUATRO methodology is also used by national audit programmes in several countries both within Europe, e.g. Belgium [11] and beyond, e.g. Philippines, Indonesia and Israel.

We report on the first 10 years of QUATRO experience in the IAEA Europe Region (defined as the European countries eligible

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to participate in the IAEA Technical Cooperation programme) with 31 centres in 21 countries audited. It represents the most comprehensive analysis of the quality of radiotherapy practices in the IAEA Europe Region available to date, including strengths, areas for improvement and needs of audited centres.

The primary aim of this present study was to identify and discuss the factors that impacted the quality of care in the audited centres. Observations presented here are potentially relevant to other centres in similar circumstances.

Materials and methods

The QUATRO methodology

QUATRO audits are organized by the IAEA in response to voluntary requests by eligible radiotherapy centres. They draw on high level international experts with broad experience in the field who comprise the auditing teams for QUATRO missions. Teams are composed of a radiation oncologist (RO), medical physicist (MP) and RTT. They receive specialized training in order to ensure consistency in the auditing approach among the teams and between geographical regions. In European audits, 26 different QUATRO experts participated (10 ROs, 8 MPs, 8 RTTs).

The QUATRO audit methodology incorporates a predefined structure with 37 check lists that guide the audit process and facilitate a standardized approach to peer review of the audited centre's infrastructure, patient and equipment related procedures, quality assurance and safety programmes, as well as professional training programmes [9]. The audit is based on staff interviews, reviews of documentation and observation of radiotherapy practices, carried out over 5 days. The health policy and economic context, within which the radiotherapy services are embedded, are also evaluated. In addition, the QUATRO physics auditor makes dosimetric measurements using IAEA equipment. QUATRO teams are assisted in their assessments by guidance for best radiotherapy practices outlined in IAEA publications [12–14] and other publicly available recommendations [15–18]. Several of these recommendations, including accreditation programmes, have been discussed by Donaldson et al. [19].

An important deliverable from a QUATRO audit is an assessment of practice quality; strengths were acknowledged and areas for improvement identified by auditors. Some centres were recognized as operating at a high level of competence (denoted as 'CC' in this paper). A CC is assessed as being capable of delivery of sustainable services to a level that can serve as a model for other radiotherapy centres, and provide training to radiotherapy professionals [9]; these criteria were the prime consideration in carrying out the audits.

The audit report is provided in confidence by the IAEA to the audited centre with the auditors' conclusion whether the centre complies with CC criteria. A brief summary together with specific recommendations that would need to be addressed at the national level is forwarded to the government of the country. A follow-up audit is available on request.

Analysis of QUATRO findings from European radiotherapy centre audits

All findings of QUATRO audits in the Europe Region were extracted from the audit reports and loaded into a spreadsheet. Recommendations were easily available for extraction but acknowledgements of good practices (commendations) were scattered in the reports' body and they were searched for by a search engine using descriptive positive attributes. For consistency, only the first audits of the 31 centres were analysed and not the follow-up audits, of which there were four. Findings were aggregated with the help of a coding key, Table 1, that consists of three category levels. Level 1 was used to differentiate between findings on staffing, infrastructure, process and the treatment centre organization. Level 2 was used to delve more deeply into these four broad categories while Level 3 was intended to provide further differentiation between findings. The authors assigned three numbers to each finding, corresponding to each coding key level so that findings could be grouped by category.

Specific recommendations to governments were analysed separately and organized by equipment, staff, education/training and government policy towards national radiotherapy programmes.

The audit results were compared between the CCs and other audited centres. A two-tailed Mann–Whitney test was used with a p-value of 0.05 to assess the statistical significance of the differences in various parameters for the two groups of centres.

Results

Profiles of the audited radiotherapy centres

The QUATRO programme generated great interest among countries in the IAEA Europe Region. Among 89 QUATRO audits in all world regions, 31 audits were conducted in 21 European countries (Fig. 1) with 14% (31/227) of all centres in the region participating. Centres which requested an audit were facilitated. Centres audited belong mostly to the public sector and include a wide spectrum of human and capital resources, extending from small to large centres and using radiotherapy technology from basic to advanced. Seventeen were national cancer centres with the infrastructure and radiotherapy services representing the level of practices achievable in the country. Figs. 2–4 display key parameters of the audited centres showing great variation in workload, equipment and staffing levels. The heterogeneity apparent with these characteristics has been observed also at the national levels in Europe [20–22]. Due to this heterogeneity data collected in this study can be considered representative of the various levels of care in the Region.

Findings

Auditors were very cognizant of the need to provide a balanced view of the programmes they were auditing. Hence, local strengths were identified as well as opportunities for improvement. Table 2 summarizes the findings from 31 European QUATRO audits structured according to the coding key developed for this project. Altogether 600 commendations and 759 recommendations for improvement were analysed.

Eight out of 31 centres were designated as CCs through the QUATRO programme on the first audit round and additionally two more centres were recognized as CCs in follow up audits. Of the total 600 commendations, 220 were given to the 8 CCs in the first audit (average 27.5 per centre) and 380 to the 23 other centres (average 16.5 per centre). Correspondingly, CCs received 82 recommendations (average 10.3 per centre) while the other centres received 677 recommendations (average 29.4 per centre). The results of a two-tailed Mann–Whitney test for the numbers of commendations and recommendations returned the p-values of 0.032 and 0.003, respectively, confirming the differences between CCs and others are statistically significant.

More information on QUATRO findings is given in the supplementary material

To extract the main messages from this huge amount of data, rows indicated in green in Table 2 highlight those topics which attracted at least twice as many commendations (C) as recommendations (R) ($C/(C+R) \geq 0.667$). Yellow indicates categories for

Table 1
The coding key developed for analysis of QUATRO findings.

Level 1	Level 2	Level 3
1. Staff	**1 radiation oncologist** **2 medical physicist** **3 radiation therapist** **4 all staff** **5 other**	**1 complement** (i.e. number of staff) **2 distribution** (i.e. are the right people doing the right jobs?) **3 remuneration/recognition** (e.g. are salary levels competitive and staff appreciated?) **4 education** (e.g. in the class room, B.Sc. programs, certification) **5 training and professional development** (e.g. clinical training, internship, residency, CPD, CME) **6 communication within and across disciplines** **7 other**
2. Infrastructure	**1 immobilization / beam modifiers/applicators/mould room** **2 RT imaging** (e.g. simulator, CT scanner, MRI, PET) **3 treatment planning system** **4 treatment machines** **5 RT data management system / record and verify** **6 multiple clinical equipment** **7 dosimetry** (e.g. ion chambers, QC equipment, in vivo dosimetry) **8 facilities** (e.g. building, privacy issues, labs, pathology diagnostic dept, IT dept) **9 other**	**1** quality of facility or equipment (e.g. fit for purpose) **2 equipment complement** (e.g. numbers of hardware-software for clinical load) **3 operating hours** **4 equipment quality control** **5 equipment commissioning** **6 maintenance** **7 other**
3. Processes	**1 patient work up** (e.g. lab, pathology, imaging, staging) **2 informed consent** **3 treatment prescription** **4 immobilization / beam modifiers/ patient marking** **5 RT imaging for planning** (e.g. simulator, CT scanner, MRI, PET) **6 treatment planning** **7 treatment delivery** **8 treatment verification/imaging** **9 multiple clinical processes** **10 quality assurance** **11 other**	**1 SOP, protocols and policies** **2 access** (e.g. hours of operation, financial, geographic) **3 checking/verification** (e.g. patient ID, plans, process QC) **4 workload** **5 process quality** **6 documentation** (e.g. records, logbooks, patients charts) **7 other**
4. Department/Institution Organization	**1 research** **2 referrals / admission** (e.g. patients' information complete) **3 discharge / follow up** (e.g. adequate information to GP, outcomes analysis, cancer registry) **4 incident learning** **5 radiation protection and safety** **6 culture and patient centredness** **7 staff responsibilities (e.g.** clear org chart, roles, job description, workflow) **8 quality and safety management** **9 clinical trials** **10 other**	**1 programme availability** **2 programme/service quality** **3 resources** **4 other**

which recommendations outnumbered commendations by at least 2:1 ($C/(C + R) \leq 0.333$). The highest numbers of commendations and recommendations in each category of findings are highlighted in bold.

In the Staff category, Table 2a presents findings broken down by profession, and Table 2b summarizes findings for all staff grouped by topic. ROs received equal numbers of commendations and recommendations (C = 12, R = 12) while MPs trended more towards commendations (C = 26, R = 15), Table 2a. For RTTs recommendations outnumbered commendations (R = 47, C = 15). This was related to understaffing and deficiencies in training in the RTT category, Supplementary Table S1. Nevertheless, all professions needed strengthening in terms of staff complement (R = 34, C = 7), distribution (R = 25, C = 8) and remuneration/recognition (R = 11, C = 0), Table 2b. Staff shortages in several centres are also visible in Fig. 4. A Mann–Whitney test used to examine the statistical significance of differences in staffing levels between CCs and other centres, resulted in the p-value = 0.339 for ROs (difference not significant), the p-value = 0.023 for MPs and the p-value = 0.005 for RTTs (both significant). Education, training and professional development received the largest number of recommendations and also commendations in the staff category (R = 69, C = 67) and for RTTs was seen a weakness in many centres, Table S1. Communication within and across disciplines was acknowledged (C = 36, R = 15), Table 2b.

In terms of Infrastructure, the facilities in the audited centres were of adequate quality (C = 98, R = 17), Table 2b, but equipment numbers were largely insufficient (R = 74, C = 8) to handle the workload. Further analysis showed that 23/31 centres were assessed by the auditors as either requiring more equipment or needing to replace some obsolete equipment. The radiotherapy machine shortage is also apparent from Fig. 3. In spite of this challenge there is, overall, a high level of auditors' satisfaction with equipment for imaging, treatment planning, and for physics services, in particular dosimetry, Table 2a. High quality dosimetry is also documented through long-term participation of medical physicists in the Region in the IAEA/WHO dosimetry audit programme [8].

The Processes of radiotherapy constituted a primary focus of the QUATRO review and, not surprisingly, this resulted in 286/759 (38%) recommendations and 166/600 (28%) commendations, Table 2a. Recommendations outnumbered commendations for treatment prescription (R = 14, C = 4) and delivery (R = 69, C = 17), verification/imaging (R = 19, C = 6), as well as multiple clinical processes involving a range of activities along the radiotherapy chain (R = 105, C = 34), Table 2a. In contrast, pretreatment workup was regarded as adequate (C = 29, R = 4) in the majority of audited centres. In particular, the quality of radiotherapy process was highly commented by the auditors (R = 112, C = 75), Table 2b. Documentation (R = 64, C = 48) and the need to

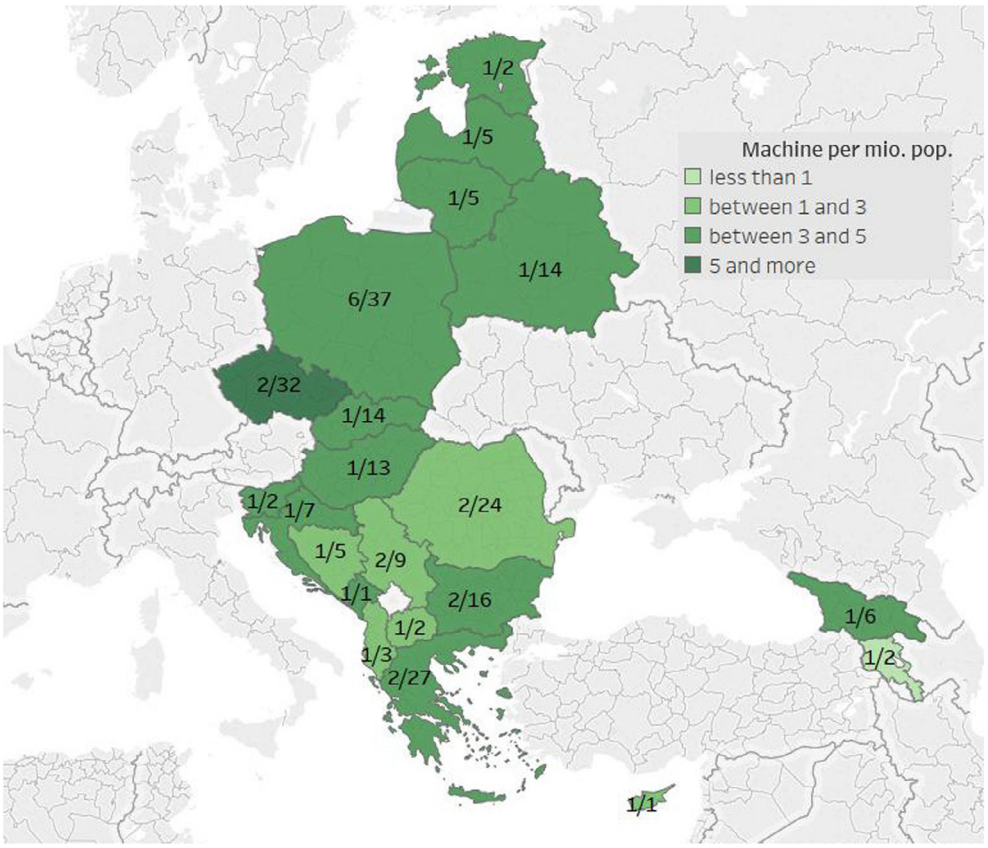

Fig. 1. Countries who participated in QUATRO audits in the IAEA Europe Region in first 10 years. The number of QUATRO audited centres is given against the number of all centres in each participating country; in total 31 of 227 (14%) centres received audits. Number of teletherapy machines per population is highlighted in shades of green (*source*: IAEA Directory of Radiotherapy Centres [23]).

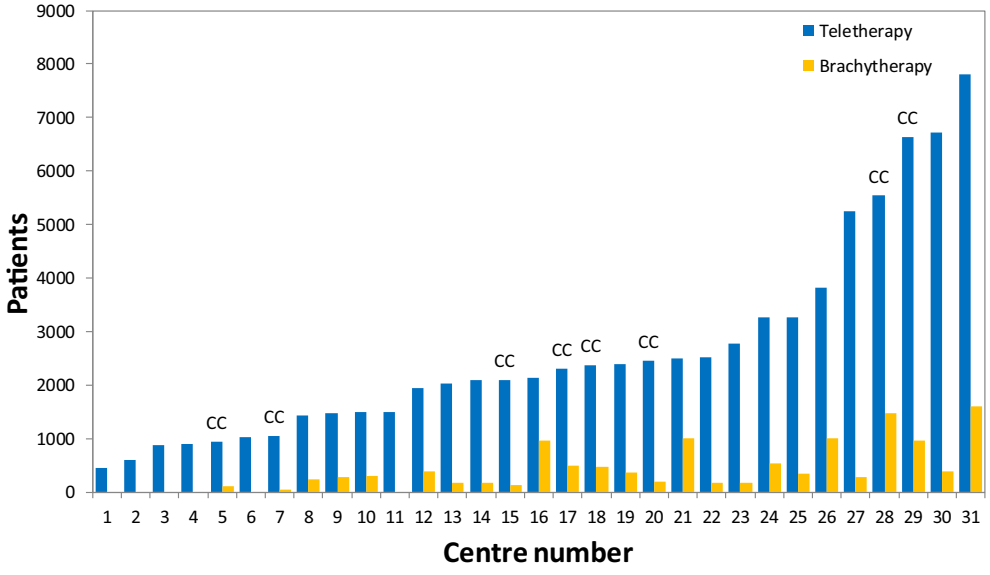

Fig. 2. Number of cancer patients treated per year in the European centres participating in QUATRO audits in 2005–2014. Centres are ordered from smallest to largest. CC denotes those centres identified through QUATRO audits as centres operating at a high competence levels. On average, there were 2676 patients treated with teletherapy per year at CCs and 2693 at other centres; patients treated with brachytherapy were 488 at CCs and 492 at other centres.

develop standard operating procedures (R = 54, C = 15) were mentioned in several audits. Overall, 93% (267/286) recommendations for improvement of the radiotherapy process were for the centres not designated as CCs.

In the Department/Institution Organization category, recommendations for improvement significantly outweighed commendations for quality and safety management (R = 96, C = 15), staff responsibilities (R = 34, C = 14) and incident reporting (R = 22,

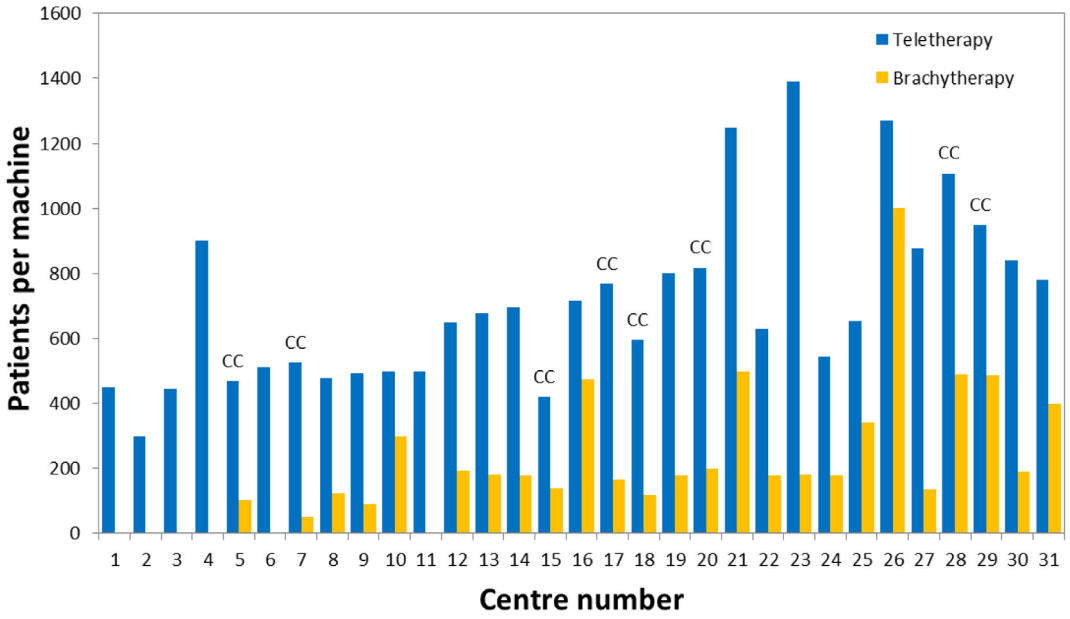

Fig. 3. Patient throughput on radiotherapy machines in 31 audited centres in Europe. Centres are ordered from smallest to largest. CC denotes those centres identified through QUATRO audits as centres operating at a high competence levels. On average, there were 700 patients treated per teletherapy unit per year at CCs and 661 at other centres; patients per brachytherapy unit were 219 at CCs and 254 at other centres.

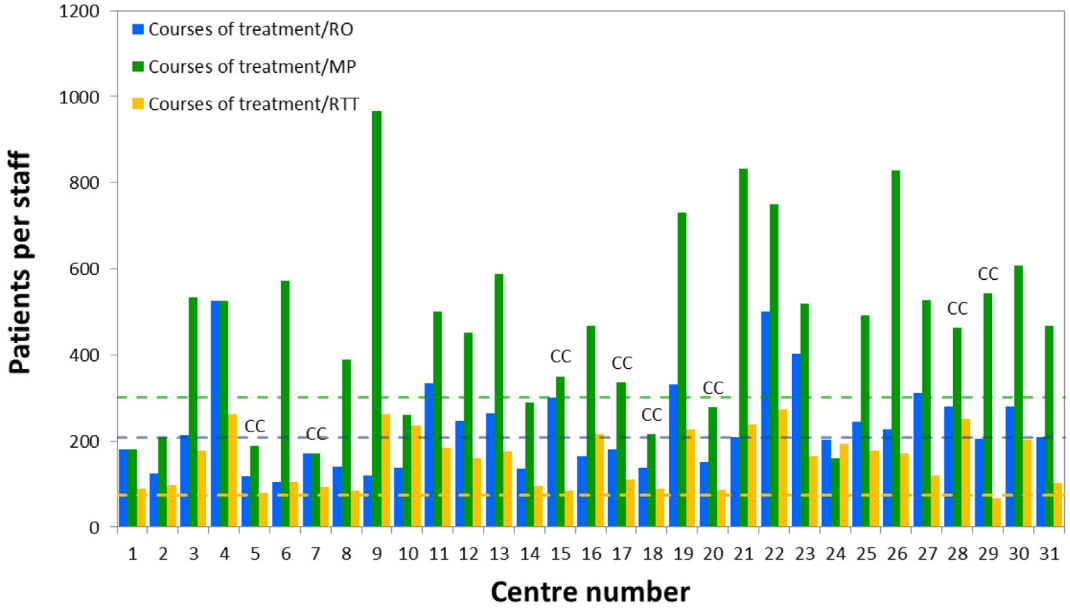

Fig. 4. Staff workload in 31 audited centres in Europe. Centres are ordered from smallest to largest. On average, FTE courses per radiation oncologist were 193 at CCs and 244 at other centres; FTE courses per medical physicist were 318 at CCs and 515 at other centres; FTE courses per RTT were 108 at CCs and 175 at other centres. Lines are shown at the level of 209 courses of treatment per year per radiation oncologist, 303 courses per year per medical physicist, 77 courses per year per RTT, representing the European averages as reported by the HERO group [20].

C = 2), Table 2a. Culture and patient centeredness was commended in most centres (C = 29, R = 16). Also, radiation protection and safety (C = 20, R = 10) were rated highly, Table 2a.

Most recommendations to government pertained to national policies for development of radiation oncology (22 audits), followed by staff education (19), equipment shortages (17) and inadequate staffing levels (14).

Discussion

One important feature of this QUATRO results' analysis was to explore the relationship between quality of practices at CCs and metrics describing the quality of care at these centres. As expected, there were remarkable differences in the number of commendations and recommendations issued for 8 CCs (C = 220, R = 82) and 23 other centres (C = 380, R = 677). All CCs had quality management systems in place, including appropriate procedures and documentation and were better staffed than other QUATRO audited centres. ROs in CCs treated on average 193 courses per year, MPs treated 318 courses and RTTs 108 courses. These numbers in other centres (RO: 244 courses, MP: 515 courses, RTT: 175 courses) suggest excessive staff workloads compared to CCs and also to the European averages reported by the ESTRO's HERO group [22]. The differences in staff workload were found statistically signifi-

Table 2
QUATRO findings (a) grouped by Level 2 codes and (b) by Level 3 codes for each of the four Level 1 categories. C denotes Commendations and R denotes Recommendations. Green indicates a ratio of Commendations to Recommendations >2:1 with C/(C + R) ≥ 0.67. Yellow indicates a ratio of Recommendations to Commendations of >2:1 with C/(C + R) ≤ 0.33. The highest numbers in each level 2 category are in bold.

(a)

	(C) (n=600)	% C	(R) (n=759)	% R	C/(C+R)
1. Staff					
Level 2	**121**	**20.2**	**155**	**20.4**	**0.4**
1 radiation oncologist	12	2.0	12	1.6	0.5
2 medical physicist	26	4.3	15	2.0	0.6
3 radiation therapist	15	2.5	47	6.2	0.2
4 all staff	**63**	10.5	**80**	10.5	0.4
5 other	5	0.8	1	0.1	0.8
2. Infrastructure					
Level 2	**213**	**35.5**	**122**	**16.1**	**0.6**
1 immobilization / beam modifiers/applicators/mould room	9	1.5	14	1.8	0.4
2 RT imaging (e.g. simulator, CT scanner, MRI, PET)	16	2.7	6	0.8	0.7
3 treatment planning system	27	4.5	9	1.2	0.8
4 treatment machines	19	3.2	23	3.0	0.5
5 RT data management system / record and verify	3	0.5	9	1.2	0.3
6 multiple clinical equipment	28	4.7	22	2.9	0.6
7 dosimetry (e.g. ion chambers, QC equipment, in vivo dosimetry)	50	8.3	13	1.7	0.8
8 facilities (e.g. building, privacy issues, labs, pathology diagnostic dept, IT dept)	**61**	10.2	**26**	3.4	0.7
9 other	0		0	0.0	
3. Processes					
Level 2	**166**	**27.7**	**286**	**37.7**	**0.4**
1 patient work up (e.g. lab, pathology, imaging, staging)	29	4.8	4	0.5	0.9
2 informed consent	7	1.2	4	0.5	0.6
3 treatment prescription	4	0.7	14	1.8	0.2
4 immobilization / beam modifiers/ patient marking	10	1.7	15	2.0	0.4
5 RT imaging for planning (e.g. simulator, CT scanner, MRI, PET)	11	1.8	14	1.8	0.4
6 treatment planning	18	3.0	18	2.4	0.5
7 treatment delivery	17	2.8	69	9.1	0.2
8 treatment verification/imaging	6	1.0	19	2.5	0.2
9 multiple clinical processes	**34**	5.7	**105**	13.8	0.2
10 quality assurance	30	5.0	24	3.2	0.6
11 other	0	0.0	0	0.0	
4. Department/Institution Organization					
Level 2	**100**	**16.7**	**196**	**25.8**	**0.3**
1 research	9	1.5	5	0.7	0.64
2 referrals / admission (e.g. patients' information complete)	1	0.2	3	0.4	0.25
3 discharge / follow up (e.g. adequate information to GP, outcomes analysis, cancer registry)	9	1.5	3	0.4	0.75
4 incident learning	2	0.3	22	2.9	0.08
5 radiation protection and safety	20	3.3	10	1.3	0.67
6 culture and patient centredness	**29**	4.8	16	2.1	0.64
7 staff responsibilities (e.g. clear org chart, roles, job description, workflow)	14	2.3	34	4.5	0.29
8 quality and safety management	15	2.5	**96**	12.6	0.14
9 clinical trials	0	0.0	4	0.5	0.00
10 other	1	0.2	3	0.4	0.25

(b)

	(C) (n=600)	% C	(R) (n=759)	% R	C/(C+R)
1. Staff					
Level 3	**121**	**20.2**	**155**	**20.4**	**0.4**
1 complement (i.e. number of staff)	7	1.2	34	4.5	0.2
2 distribution (i.e. are the right people doing the right jobs?)	8	1.3	25	3.3	0.2
3 remuneration/recognition (e.g. are salary levels competitive and staff appreciated?)	0	0.0	11	1.4	0.0
4 education (e.g. in the class room, B.Sc. programs, certification)	11	1.8	12	1.6	0.5
5 training and professional development (e.g. clinical training, internship, residency, CPD, CME)	**56**	9.3	**57**	7.5	0.5
6 communication within and across disciplines	36	6.0	15	2.0	0.7
7 other	3	0.5	1	0.1	0.8
2. Infrastructure					
Level 3	**213**	**35.5**	**122**	**16.1**	**0.6**
1 quality of facility or equipment (e.g. fit for purpose)	**98**	16.3	17	2.2	0.9
2 equipment complement (e.g. numbers of hardware-software for clinical load)	8	1.3	**74**	9.7	0.1
3 operating hours	0	0.0	1	0.1	0.0
4 equipment quality control	57	9.5	3	0.4	1.0
5 equipment commissioning	19	3.2	9	1.2	0.7
6 maintenance	31	5.2	16	2.1	0.7
7 other	0	0.0	2	0.3	0.0
3. Processes					
Level 3	**166**	**27.7**	**286**	**37.7**	**0.4**
1 SOP, protocols and policies	15	2.5	54	7.1	0.2
2 access (e.g. hours of operation, financial, geographic)	13	2.2	8	1.1	0.6
3 checking/verification (e.g. patient ID, plans, process QC)	14	2.3	47	6.2	0.2
4 workload	1	0.2	1	0.1	0.5
5 process quality	**75**	12.5	**112**	14.8	0.4
6 documentation (e.g. records, logbooks, patients charts)	48	8.0	64	8.4	0.4
7 other	0	0.0	0	0.0	0.0
4. Department/Institution Organization					
Level 3	**100**	**16.7**	**196**	**25.8**	**0.3**
1 programme availability	42	7.0	**137**	18.1	0.2
2 programme/service quality	**53**	8.8	45	5.9	0.5
3 resources	5	0.8	13	1.7	0.3
4 other	0	0.0	1	0.1	0.0

cant and clearly demonstrate the importance of adequate staffing levels for achieving superior operational quality. The correlation between the human resources availability and quality aspects of care cannot be overstated.

Interestingly, no significant relationship between staff workload and the centre size or patient throughput on machines was found in this study. Also noted was that teletherapy machine workload was high in CCs (700 courses per machine per year) and other audited centres (661 courses per machine per year) compared to 400–450 benchmarked by IAEA [20] and ESTRO [21]. Nevertheless, CCs were able to adopt modern technology and optimize their resource use by employing adequate staff numbers and operating equipment in shifts, at the same time ensuring high quality radiotherapy services to their patients.

QUATRO recommendations to governments suggest that national policies for radiotherapy services are required in several countries and these should lead to significant investments in equipment and personnel to enable centres to provide adequate service levels to the population. In fact, the average number of radiotherapy machines per million in 21 audited countries is 3.5 compared to 8.3 machines per million in Western Europe [23]. Some countries, such as the Netherlands [24] have implemented forward planning for radiotherapy at the national level, resulting in greater availability of radiotherapy services to patients.

Noted areas requiring improvement were education, training and professional development, attracting 45% (69/155) of recommendations in the staff category, Table 2b. Education programmes need to be developed and promoted, particularly for RTTs, but also for medical physicists, where shortages exist. Many organizations, including the IAEA and ESTRO, have developed core curricula [25–30] for all three disciplines and operate active training programmes. However, extensive as these programmes are, more efforts should be directed towards implementing the academic and clinical components of core curricula at national levels and possibly harnessing modern communication technology in order to reach a broader audience within the radiotherapy community [1].

Issues related to radiotherapy process attracted 38% (286/759) of all QUATRO recommendations. In particular, many recommendations were given on process quality and documentation (R = 112), and standard operating procedures (R = 118). Combined, they constituted 80% (230/286) of recommendations related to the radiotherapy process. As mentioned above, 93% (267/286) of these recommendations were for the centres not designated as CCs. It is well known that the absence of appropriate procedures and documentation and/or failure to follow approved procedures is an important contributor to incidents in radiotherapy [31]. Issues surrounding documentation are by no means unique to the audited centres. Data from the Safety Profile Assessment launched by the American Association of Physicists in Medicine [32] identified documentation issues as a weakness in many of the contributing centres. Some advice on the format and content of appropriate documentation exists [33] but more practical help in this area is now needed.

There was a great diversity of recommendations for quality and safety management covering a range of quality related issues. Certain areas of the audited programmes had well documented quality control protocols with all relevant records in place. However,

several centres were lacking comprehensive approaches to management of both quality and safety. Adoption of prospective risk management techniques, such as Failure Modes and Effects Analysis [34], was not noted in any report. Incident reporting and learning systems were acknowledged in two centres only, requiring such developments in many departments. Training on incident reporting is needed at national levels. For the overall quality of radiotherapy services, the opportunity is to implement an integrated quality management system covering all aspects of quality and safety. A similar observation of a lack of formal quality management has been made in an analysis of QUATRO audits in Latin America [35]. Innovative and practical strategies are probably desirable if the general level of quality management in radiotherapy is to be raised. Professional organizations should be encouraged to provide opportunities for education and fellowships. Centres should be encouraged to appoint professional quality managers.

Overall, the findings from the Europe Region were closely parallel to those from USA [32] with the major exception of equipment availability. Adequate documentation, incident learning and quality management systems seem to be weak everywhere. However, a very positive feature of most centres, as reported by QUATRO auditors, was the dedication of staff to ensuring the best patient care achievable in the local circumstances.

It is noted that this study has some limitations. As data from QUATRO reports pertain to a 10 year time span, a comparison of human and technological resources between the audited centres does not reflect newer developments in centres audited in the early years; likely, some of these developments were triggered by the QUATRO findings. It is also noted that the nature of the QUATRO findings varied widely. Some recommendations were based on identification of areas of poor practices, others referred to aspects of refinement for radiotherapy programme components; while some others provided directions for future developments. Even though auditors were very experienced international experts well trained in QUATRO methodology, some variation between reports was unavoidable and the aggregation within the coding key relied to some extent on the judgement of the authors of this paper. Also, on some occasions quantification of the workload information was challenging due to uncertainties in data provided by centres. Due to the voluntary nature of QUATRO audit requests, it is likely that the centres motivated to improve their practices applied, with the practices in other centres unknown. Despite these potential shortcomings, this study offers the most complete overview of quality of care in the Europe Region currently available.

Conclusions

This analysis of QUATRO findings reflects the different dimensions of radiotherapy service quality and suggests interventions which are likely to be effective in improving quality. While there are recognizable strengths in the audited centres, there are gaps to be addressed including equipment availability, staffing, education and training, and quality management. The centres recognized by QUATRO as centres of competence distinguished themselves from other centres by having complete quality management systems in place and adequate number of professionals to ensure optimal patient care. Overall, the commitment of staff to providing a positive environment for their patients was commendable in all centres.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.radonc.2017.09.011.

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