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Datum: 16 02 2018

UNIVERZITET CRNE GORE

-Centar za doktorske studije-

U prilogu akta dostavljamo Odluku Vijeća Prirodno-matematičkog fakulteta sa XIV sjednice održane dana 09.02.2018. godine, za doktoranda Sonju Ivanović, na dalje postupanje.

DEKAN
Prof. dr Predrag Miranović

Univerzitet Crne Gore
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Broj: 418

Datum: 13 02 2018

Na osnovu člana 64 stav 2 tačka 8 Statuta, a u vezi sa članom 43 I 44 Pravila doktorskih studija Univerziteta Crne Gore, Vijeće Prirodno-matematičkog fakulteta na XIV sjednici održanoj dana 09.02.2018. godine, donijelo je

ODLUKU

I

Prihvata se Izvještaj komisije za ocjenu doktorske disertacije pod nazivom *"Unapređenje kontrole kvaliteta i osiguranje kvaliteta (QA i QC) u skriningu i dijagnostičkoj mamografiji u Crnoj Gori"* kandidata mr Sonje Ivanović.

II

Predlažemo Senatu Univerziteta Crne Gore **da prihvati** disertaciju *"Unapređenje kontrole kvaliteta i osiguranje kvaliteta (QA i QC) u skriningu i dijagnostičkoj mamografiji u Crnoj Gori"* kadidata mr Sonje Ivanović i imenuje komisiju za odbranu doktorske disertacije u sastavu:

1. Dr Hilde Bosman, vanredni profesor, Katolički Univerzitet Luven, Belgija, medicinski fizicar, (naučna oblast: Medicinska fizika zračenja i Radiologija);
2. Dr Olivera Ciraj Bjelac, vanredni profesor ETF-a, Univerziteta u Beogradu, naučni savjetnik Univetziteta u Beogradu, Institut za nuklearnu nauku - Vinča; medicinski fizicar (naučna oblast: Nuklearna tehnika);
3. Dr Slavoljub Mijovic, redovni profesor Prirodno - matematičkog fakulteta Univerziteta Crne Gore (naučna oblast: Atomska fizika, Jonizovani gasovi i Zaštita od zračenja);
4. Dr.Mara Scepanovic, redovni profesor Prirodno-matematičkog fakulteta Univerziteta Crne Gore (naučna oblast: Atomska fizika, Jonizovani gasovi i Zaštita od zračenja);
5. Dr Mira Vuceljic, redovni profesor Prirodno-matematičkog fakulteta Univerziteta Crne Gore (naučna oblast: Atomska fizika, Jonizovani gasovi i Zaštita od zračenja);

III

Predlog se dostavlja Centru za doktorske studije i Senatu Univerziteta Crne Gore na dalju proceduru.

D E K A N

Prof. dr Predrag Miranović

UNIVERZITET CRNE GORE Prirodno-matematički fakultet UCG

OCJENA DOKTORSKE DISERTACIJE

OPŠTI PODACI O DOKTORANDU		
Titula, ime i prezime	Mr Sonja Ivanović	
Fakultet	Prirodno-matematički fakultet	
Studijski program	Fizika	
Broj indeksa	01/12	
MENTOR/MENTORI		
Prvi mentor	Prof. dr Slavoljub Mijović	UCG, PMF, Crna Gora
Drugi mentor	Van. prof. dr Hilde Bosman	Katolički Univerzitet, Medicinski fakultet, Belgija

KOMISIJA ZA OCJENU DOKTORSKE DISERTACIJE	
Van. prof. dr Olivera Ciraj Bjelac	Univerzitet u Beogradu, Elektrotehnički fakultet, Srbija
Vanr. prof. dr Hilde Bosman	Katolički Univerzitet, Medicinski fakultet, Belgija
Prof. dr Slavoljub Mijović	UCG, PMF, Crna Gora
Prof. dr Mara Šćepanović	UCG, PMF, Crna Gora
Prof. dr Mira Vučeljić	UCG, PMF, Crna Gora

Datum značajni za ocjenu doktorske disertacije	
Doktorska disertacija i Izvještaj Komisije dostavljen Biblioteci UCG	27.12. 2017.
Javnost informisana (dnevne novine) da su Doktorska disertacija i Izvještaj Komisije dati na uvid	28. 12. 2017. (dnevne novine Vijesti)
Sjednica Senata na kojoj je izvršeno imenovanje komisije za ocjenu doktorske disertacije	16. 10. 2017.

Uvid javnosti	
U predviđenom roku za uvid javnosti bilo je primjedbi?	ne

OCJENA DOKTORSKE DISERTACIJE

1. **Pregled disertacije** (bibliografski podaci o disertaciji i sažetak disertacije)

Doktorska disertacija pod naslovom „**Unapređenje kontrole kvaliteta i osiguranje kvaliteta (QA i QC) u skriningu i dijagnostičkoj mamografiji u Crnoj Gori**“, kandidata mr Sonje Ivanović je napisana na 83 stranice A4 formata. Sastoji se od 7 poglavlja, spiska literature sa 52 citirane bibliografske jedinice i biografije autora.

Sonjina teza je prva ove vrste u Crnoj Gori i zbog toga je odlučila da napravi sveobuhvatan dokument. Teza je trebala biti i cjelovita, tako da je kandidat bio zamoljen da uključi i poglavlje o osnovnoj teoriji i opremi za upotrebu u skriningu raka dojke. Uz to, svi dobijeni rezultati istraživanja su uključeni. Sadržaji objavljenih naučnih radova su takođe

uključeni u rukopis.

Prvo poglavlje definiše rad na tezi.

Skrining raka dojke je u većini zemalja svijeta veliki zdravstveni problem za žene. Sonja objašnjava osnove bolesti, kao i kako se rak manifestuje u rendgenskim snimcima. Obično se vide razlike u kontrastu slika mekih tkiva (veličine> 2 mm) i sitnih kalcifikacija, koje se pod pravilnim rendgenskim uslovima mogu vidjeti i kada su reda veličine 100 μm. U drugom dijelu uvoda objašnjava se rendgenska tehnika. Iako postoji opsežna literatura u vezi s najnovijom digitalnom rendgenskom tehnikom, Sonja se odlučila da uglavnom koristi materijal nove knjige od strane Agencije za atomsku energiju (IAEA), 'Dijagnostička radiološka fizika', priručnik za nastavnike i studente 'D.R. Dance, S. Christofides, A.D.A. Maidment, I.D. McLean i K.H. Ng. Knjiga je objavljena 2014. godine.

Drugo poglavlje postavlja probleme koji će se rešavati u tezi i plan rada kako raditi na njima.

Poglavlje 3. Testiranje novih dozimetara.

Poglavlje 4. Digitalne slike su sa šumom. Sonja je radila na problemima naknadne obrade slike (post-procesiranje) u cilju redukcije šuma.

Poglavlje 5. Ovo poglavlje opisuje prve korake prema primjeni cjelovitog protokola na mamogramskim jedinicama u Crnoj Gori, koja ima 15 film-skrin jedinica i jednu CR jedinicu.

Poglavlje 6. Primijenjen je test protokol na CR mamografski sistem.

Poglavlje 7. Urađena su prva istraživanja QC na nedavno instaliranom sistemu digitalne tomosinteze grudi (DBT) u Crnoj Gori.

2. Vrednovanje disertacije

2.1. Problem

Generalni problem u radiološkom slikanju ljudskog tijela je dobijanje relevantne informacije iz snimka uz minimalno ozračivanje pacijenta. To je naročito važno u mamografiji, gdje vizualizacija važnih detalja (anomalno tkivo), zahtjeva separaciju „interesantnih struktura" od „pozadine" (tj., mikrokalcifikacija od glanularnog tkiva).

Dakle, problem optimizacije i kompromisa između kvaliteta slike i radijacionog izlaganja je bio osnovni zadatak u ovoj tezi. Pošto optimizacija u ovom slučaju zavisi od mnogo parametara (radiografkih jednica-mamografa, generatora x-zraka, detektora signala, pacijentnih karakteristika,...), sveobuhvatna mjerenja i analiza podataka na svim mamografskim jedinicama u Crnoj Gori su se morala uraditi.

2.2. Ciljevi i hipoteze disertacije

Skrining raka dojke je u većini zemalja svijeta veliki zdravstveni problem za žene. Generalni cilj ove teze su istraživanja i poboljšavanja metoda za procjenu prosječne glandularne doze (AGD) i kvaliteta slike u mamografiji kao i razumjevanje korelacije između fizičkih i tehničkih parametara sa kliničkim kvalitetom slike.

Specifični ciljevi su bili:

- evaluacija tehničkih karakteristika mamografskih jedinica u Crnoj Gori;
- poboljšanje metoda za procjenu prosječne glandularne doze i kvaliteta slike;
- uspostavljanje nacionalnih referentnih nivoa doza sa podacima, dobijenih u skladu sa međunarodnim standardima;
- provjera pouzdanosti automatskih mjerenja filterima pomoću multimetra MagicMax.

Osim toga, nova tehnologija tomosinteze se morala istraživati tehničkim testovima.

2.3. Bitne metode koje su primijenjene u disertaciji i njihovu primjerenost. Ako je primijenjena nova ili dopunjena metoda, opišite šta je novo

Putem IAEA projekta RER 6004, Kliničkom centru je dostavljen kompletan set za testiranje mamografskih jedinica. Od posebne važnosti za ovaj rad je novi multimetar 'MagicMax' i antropomorfni fantom (vidi poglavlje 6).

Novi dozimetar je jedinstven, u smislu da u jednoj ekspoziciji simultano mjeri radijacioni izlaz cijevi, brzinu radijacionog izlaza, napon na cijevi, anoda/filter kombinaciju i poludebljinu (HVL). Ovaj jedinstveni pristup nameće potrebu istraživanja u smislu tačnosti uređaja sa naročitim akcentom na mjerenja HVL-a.

Kao testni protokoli korišćeni su Evropske smjernice za osiguranje kvalitete u skriningu raka dojke i IAEA protokol. U žiži ispitivanja je bila sigurnost (detaljno ispitivanje rendgenskih cijevi i x-snopova), doza pacijenata i kvalitet slike. Pošto su 14 od 15 jedinica film-skrin sistemi, senzitometrijska i denzitometrijska spitivanja su bila krucijalna.

AGD je raunata Dance-ovim metodom, što je takođe opisano u Evropskom protokolu za kontrolu kvaliteta fizičkih i tehničkih aspekata skrin-film mamografije. Doza je određivana korišćenjem standardnih kliničkih odabranih faktora izlaganja sa automatski kontrolisanom ekspozicijom (AEC) i PMMA 180 x 240 mm blokova, debljina od 20, 30, 40, 45, 50, 60 i 70 mm. Mjereni su vazdušna kerma na mestu upada zraka i HVL. Po prvi put se procjenjuju doza u mamografiji u Crnoj Gori na sistematski način. Dobro je poznato da su doze, određene na ovaj način tj., pomoću fantoma, dobri reprezenti doza koje primaju žene uz uslov da se koristi isti AEC.

2.4. Rezultati disertacije i njihovo tumačenje

U prvom radu Sonja je provjerila koliko dobro eksponencijalna funkcija odgovara eksperimentalnim podacima, mjerenim jonizacionom komorom, koja ima svojstvo 'zlatnog standarda' za određivanje HVL-a. Uočeno je da se svi eksperimentalni podaci dobro fituju sa eksponencijalnom funkcijom (koeficijenti korelacije su u većini slučajeva bili bolji od 99%), bez obzira na činjenicu da rendgenski zraci nisu mono-energetski.

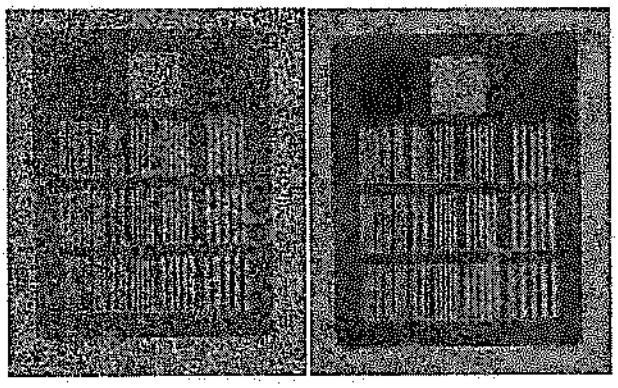
Drugi zadatak je bio procjena mjerne greške u određivanju HVL. Ocijenjeno je da je greška mjerenja HVL-a manje od 10% (obično je bila manja od 6%). Konačno je potvrđena metoda koja je predložena u mnogim protokolima za kontrolu kvalitete procjene HVL-a i sastoji se iz tri mjerenja.

U drugom dijelu poglavlja kandidat se bavio mjerenjima Magic-Max dozimetrom u

jednoj ekspoziciji. Izvršena je provjera pouzdanosti kvaliteta x-zraka. Podaci izmjereni MagicMax-om su upoređivani sa mjerenjima jonizacionom komorom. Ova studija bila je dio šireg proučavanja koja je uključivala nekoliko drugih dozimetara (tekst se planira za štampu). U tezi se također provjerava i tačnost mjerenja napona cijevi. Test se temelji na pretpostavci da ako se isti kVp primijeni na različite anoda/filter kombinacije jednog te istog uređaja, izmjereni kVp bi trebali biti isti. Rezultati su potvrđivali pouzdanost mamografskih jedinica.

Razlike između direktnih mjerenja HVL –a sa MagicMax-om i mjerenja jonizacionom komorom nisu prelazile više od 0,02 mm Al. To je manje od standardne devijacije, pa su time i mjerenja MagicMax-om prihvatljiva. Zatim je primijenjena Robsonova metoda: u ovom pristupu HVL je procijenjivano u rasponu od 26 kVp do 32 kVp, sa mjerenjem HVL na 28 kVp. Za testirane anoda/filter kombinacije (zapravo Mo/Rh), odstupanja izmjerenih i ekstrapoliranih podataka su vrlo mala. Izvan raspona za kVp, koji je predložio Robson, tj. pri 24 kVp ili 34 kVp, odstupanja su veća, ali još uvek unutar granica, postavljenih bilo kojim QC protokolom.

Oštrina slike mamografske jedinice se obično karakteriše njenom funkcijom širenja tačke (PSF) ili njenom modulacionom transfer funkcijom (MTF), u slučaju ako se jedinica ponaša kao linearno invarijantna na pomeraj. Nađen je efikasni metod za vraćanje oštrine digitalnih mamograma pomoću postupaka dekonvolucije. Nema više pojedinosti o metodi u tekstu (više pitanja se mogu postaviti tokom obrane teze), ali su rezultati ilustrirani:



Rekonstruisana testna slika korišćenjem metodologije 1 (levo) I metodologije 2 (desno)
Metod nije ilustrovan na kliničkim snimcima

Rezultati određivanja AGD su prikazani u Tabeli niže:

AGD vrednosti za 15 mamografskih jedinica, uporedo sa graničnim vrednostima

mamm o jedinic a	D_{20mm} PMMA (mGy)	D_{30mm} PMMA (mGy)	D_{40mm} PMMA (mGy)	D_{45mm} PMMA (mGy)	D_{50mm} PMMA (mGy)	D_{60mm} PMMA (mGy)	D_{70mm} PMMA (mGy)
1	0.91	2.35	3.84	4.39	5.02	5.47	6.7
2	0.76	1.18	1.83	2.09	2.46	3.62	5.56
3	0.68	1.07	1.63	1.96	2.32	3.51	4.91
4	0.56	0.85	1.32	1.49	1.79	2.66	3.91

5	0.54	0.85	1.36	1.63	1,98	2.86	4.32
6	0.77	1.07	1.49	1.55	1.71	2.21	3.96
7	0.45	0.71	1.16	1.36	1.67	2.48	3.75
8	0.48	0.73	1.15	1.21	1.49	2.11	2.91
9	0.48	0.42	0.51	0.64	0.66	0.64	0.75
10	0.75	1.16	1.81	2.21	2.64	3.81	6.02
11	0.92	1.46	2.33	2.81	3.86	4.27	7.74
12	0.53	0.82	1.41	1.7	2.07	3.5	6.36
13	0.87	1.21	1.78	2.13	2.49	3.64	5.38
14	0.8	1.26	1.97	2.42	2.91	4.21	6.56
15	0.42	0.65	1.02	1.19	1.43	2.07	2.78
Prihvatljivo	<1.0	<1,5	<2.0	<2.5	<3.0	<4.5	<6.5
Dostižno	<0.6	<1.0	<1.6	<2.0	<2.4	<3.6	<5.1

Podaci jedinice 9 nisu korišćeni, budući da su ocijenjeni kao neodgovarajući. Iz preostalih podataka izračunati su prvi dijagnostički referentni nivoi (DRL). Da bi se to postiglo, eksperimentalni podaci svih debljina su fitovani sa normalnom (Gaussovom) raspodjelom i ocjenom srednjih vrijednosti i standardnih odstupanja. Zatim je uzeta vrednost doze na 75% Gausove raspodjele za referentni nivo AGD-e. Vrijednosti su prikazane u sljedećoj Tabeli:

Predloženi DRL za skrining mamografiju u Crnoj Gori

Debljina PMMA (mm)	**Equivalentna debljina dojke (mm)**	**Predloženi DRL (mGy)**
20	21	0.8
30	32	1.4
40	45	2.1
45	53	2.5
50	60	3.0
60	75	3.9
70	90	6.0

Kvalitet slike sa aspekta optičke gustine nije na odgovarajućem nivou. U većini centara se ne koristi odgovarajuće procesiranje filma. Zaključak ovog rada je- urgentna optimizacija prakse.

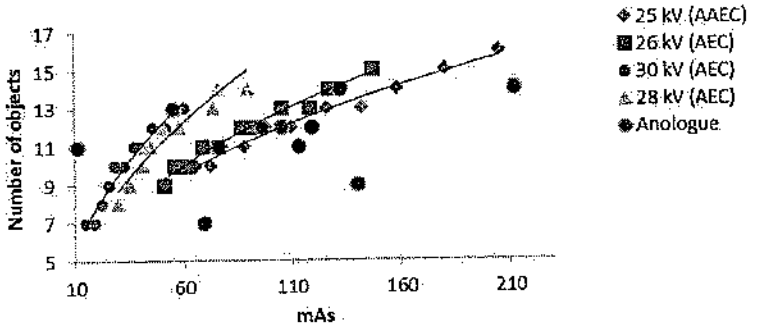
Primijenjen je test protokol na CR mamografski sistem i time je omogućen početak uvođenja protokola u osiguranju kvaliteta (QA) za digitalne jedinice u Kliničkom Centru u Crnoj Gori. Ciljevi tog dela rada su bili: (1) izgradnja testovnih procedura za QA u digitalnoj mamografiji sa novim testovnim uređajima, uključujući MagicMax multimetar (IBA, Nemačka) i tkivu ekvivalentan antropomorfni fantom Mammo AT (IBA, Nemačka) i (2) određivanje da li prvi digitalni CR sistem u Crnoj Gori zadovoljava današnje Evropske standarde.

Mamografski sistem koji se koristi u Kliničkom centru Crne Gore se sastoji od različitih komponenti, koji zajedno čine cjeloviti lanac za snimanje: Planmed Sophie

mamografski rendgenski uređaj, Konica Minolta CR mamografske ploče za snimanje RP-6M, čitač Konica Minolta Regius 190 CR, Kodak Dry View 6800 laserski pisač, Rogan View Pro-X radna stanica i ekran za gledanje snimaka. Testovi su uglavnom izvedeni iz Evrropskog protokola i uključuju: radijacioni izlaz cijevi (μGy / mAs), brzinu radijacionog izlaza (mGy/s), reproducibilnost i tačnost napona cijevi, poludebljinu, reproducibilnost i tačnost AEC sistema, kontrole koraka ekspozicije, funkciju odziva receptora, kvalitet slike i test stabilnosti pisača. Prosječna glandularna doza je određivana i pikazana u poglavlju 5. Rezultati su sažeti u naučnom članku i predstavljeni na Konferenciji u Varni 2014. godine. U tom članku je glavni fokus bio na tkivu ekvivalentnom antropomorfnom fantomu Mammo AT (IBA). Pošto ovaj antropomorfni fantom nije imao nikakvih ograničavajućih vrijednosti u smislu neprihvatljivosti, bio je primijenjen na svim film-skrin jedinicama kako bi se dobili prvi referentni nivoi doza. Tada su se novi digitalni podaci mogli porediti sa DRL. Ovo je u skladu s pristupom koji je usvojen za CDMAM fantom pri prijelazu s film-skrin jedinica na digitalno snimanje. Međutim, u ovom radu je upozoreno da kvalitet film-skrin jedinica nije verifikovan. Ipak, mišljena smo da sa ovim fantomom možemo garantovati da kvalitet digitalnih sistema neće biti slabiji od trenutne prakse u zemlji s film-skrin sistemima, ako bi ista količina detalja na fantomu bila vidljiva. Pošto CR sistem može da funkcioniše na više doznih nivoa, sve doze kandidati su bili testirani i upoređivani sa rezultatima film-skrin jedinica sa aspekta vidljivih detalja.

Kako bi se dobile referentne vrijednosti film-skrin jedinica, sniman je fantom na 11 konvencionalnih mjesta, testiranih od strane ovlašćenih tehničkih servisa Crne Gore. Na tri Siemens jedinice, fantom je bio izlagan manuelno dok nije dobijena odgovarajuća optička gustina. Na ostalim konvencionalnim jedinicama (Planmed Sophie Classic - Finska) korišćen je AEC način rada. Na konvencionalnim sistemima broj vidljivih objekata je bio između 7 i 14. Ocijenjeno je da je granični broj vidljivih detalja od 7 ÷9 sumnjiv za performansu sistema i predlaženo je kao minimalni kriterij '11 objekata koji se mogu detektovati'.

Fantom se tada izlagao x-snopu CR jedinice, menjajući korak od -5 do +5 s AEC (fiksnim kV i Mo-Mo) i AAEC (automatski izbor anode/filter i kVp). U kliničkoj praksi, korak 0 je bio u upotrebi. Može se vidjeti da je u kliničkom režimu sa AEC i korakom 0 ispunjen minimalni kriterij od 11 objekata za sve napone cijevi ispod 30 kVp. To nije bio slučaj pri naponu od 30 kV, i razloge za to vrijedi istražiti.



Kvalitet snimka dobijen sa IBA fantomom za sve vrijednosti kVp i uzastopnim AEC koracima od -5 to +5. Analogni sistemi su prikazani sa crvenim krugovima. Preporučena vrijednost: 11 objekata.

Rezultati istraživanja su pokazali da je moguće postići QA na digitalnom CR mamografu, korišćenjem IBA fantoma. Ovaj projekt je poslužio, istovremeno i za istraživanje i za obuku. Zaključeno je da:

(1) su svi mjereni parametri unutar opsega, opisanog u Evropskim protokolima, osim napona cijevi koji je odstupao više od ± 1kV. Automatsko određivanje HVL-a je bilo zadovoljavajuće. Prosječna glandularna doza je bila od 0,66 do 7,02 mGy za debljine PMMA od 20 do 70mm i bila je u skladu sa podacima iz literature.
(2) Ocjena kvaliteta slike koja je dobijena tkivu ekvivalentnim antropomorfnim fantomom Mammo AT za CR sistem je bila slična rezultatima dobijenim iz konvencionalne mamografije s filmom.

U posljednjem poglavlju sprovedeno je ispitivanje prihvatljivosti puštanja sistema u rad, koristeći preliminarni protokol EUREF tima. Svi su testovi izvedeni zajedno s profesorom Nicholasom Marshallom (KU Leuven). Izvještaj je uključen i komentarisan u rukopisu. Rezultati su bili u skladu s rezultatima na drugim Hologic sistemima koje su ranije testirali drugi timovi. Sonja sada može periodično reprodukovati ta mjerenja.

3. Konačna ocjena disertacije

Prvi put su bili primijenjeni protokoli QC na film-skrin, CR i DBT jedinicama. Predložen je prvi crnogorski DRL za mamografiju. Na temelju svih iskustva dobijenih QC-om na film-skrin, CR i DR s tomosintezom, Sonja je sada dobro pripremljena za globalno izvođenje QC-a u screeningu dojke, korišćenjem najnovijih Evropskih i IAEA smjernica. Ovo je glavno dostignuće i izražavamo nadu da će se ova stručnost koristiti u zemlji.

Orginalni naučni doprinos

Glavni naučni doprinosi ove teze su procjena nesigurnosti određivanja vrijednosti poludebljine u mamografiji; provjera automatiziranih mjerenja filterima s novim MagicMax detektorom i potvrđivanje Robsonove parametrizacije za ocjenjivanje svih HVL-ova iz jednog mjerenja na 28 kVp. Sljedeći doprinos je predložena rekonstrukcija snimka bazirana na Wiener-ovim filterima.

Mišljenje i prijedlog komisije

Visok kvalitet QA i QC u mamografiji je od izuzetne važnosti za rano otkrivanje raka dojke. Na početku rada na ovoj tezi u Crnoj Gori nije bio razvijen QC mamografskih sistema. Sa mjerenjima sprovedenim u ovoj tezi, nivo QC je znatno povećan. Započelo se s primjenom smjernica EU i IAEA za QC u mamografiji i Sonja je dobila prve rezultate.

Komisija predlaže Vijeću Prirodno-matematičkog fakulteta i Senatu Univerziteta Crne Gore da prihvati pozitivnu ocjenu ponuđenog teksta i odobre javnu odbranu disertacije kandidatu mr Sonji Ivanović pod naslovom „**Unapređenje kontrole kvaliteta i osiguranje kvaliteta (QA i QC) u skriningu i dijagnostičkoj mamografiji u Crnoj Gori**".

KOMISIJA ZA OCJENU DOKTORSKE DISERTACIJE	
Vanredni profesor dr Hilde Bosmans, Katoločki Univerzitet u Luvenu, Medicinski fakultet, Belgija	
Vanredni profesor dr Olivera Ciraj Bjelajac, Univerzitet u Beogradu, elektrotehnički fakultet, Srbija	
Redovni profesor dr Slavoljub Mijović, Univerzitet Crne Gore, Prirodno-matematički fakultet, Crna Gora	
Redovni profesor dr Mara Šćepanović, Univerzitet Crne Gore, Prirodno-matematički fakultet, Crna Gora	
Redovni profesor dr Mira Vučeljić, Univerzitet Crne Gore, Prirodno-matematički fakultet, Crna Gora	
Datum i ovjera (pečat i potpis odgovorne osobe)	
U Podgorici, 9.02.2018.	DEKAN

VIJEĆU PRIRODNO-MATEMATIČKOG FAKULTETA I SENATU UNIVERZITETA CRNE GORE U PODGORICI

PREDMET: Ocjena doktorske disertacije mr Sonje Ivanović

Na sjednici Senata Univerziteta Crne Gore, održanoj 16.10.2017. godine, imenovana je Komisija u sastavu dr Hilde Bosmans (vanredni profesor Medicinskog fakulteta u Luvenu), dr Olivera Ciraj Bjelajac (vanredni profesor elektrotehničkog fakulteta u Beogradu), dr Slavoljub Mijović (redovni profesor Prirodno-matematičkog fakulteta u Podgorici), dr Mara Šćepanović (redovni profesor Prirodno-matematičkog fakulteta u Podgorici), dr Mira Vučeljić (redovni profesor Prirodno-matematičkog fakulteta u Podgorici), sa zadatkom da pregleda i ocijeni doktorsku disertaciju pod naslovom „**Unapređenje kontrole kvaliteta i osiguranje kvaliteta (QA i QC) u skriningu i dijagnostičkoj mamografiji u Crnoj Gori**“, kandidata mr Sonje Ivanović.

Komisija je pregledala tekst disertacije i podnosi Vijeću i Senatu sljedeći

IZVJEŠTAJ

I Tema i cilj doktorske disertacije

Skrining raka dojke je u većini zemalja svijeta veliki zdravstveni problem za žene. Generalni cilj ove teze su istraživanja i poboljšavanja metoda za procjenu prosječne glandularne doze (AGD) i kvaliteta slike u mamografiji kao i razumjevanje korelacije između fizičkih i tehničkih parametara sa kliničkim kvalitetom slike.

Specifični ciljevi su bili:

- evaluacija tehničkih karakteristika mamografskih jedinica u Crnoj Gori;
- poboljšanje metoda za procjenu prosječne glandularne doze i kvaliteta slike;
- uspostavljanje nacionalnih referentnih nivoa doza sa podacima, dobijenih u skladu sa međunarodnim standardima;
- provjera pouzdanosti automatskih mjerenja filterima pomoću multimetra MagicMax.

Osim toga, nova tehnologija tomosinteze se morala istraživati tehničkim testovima.

II Struktura i rezultati disertacije

Sonjina teza je prva ove vrste u Crnoj Gori i zbog toga je odlučila da napravi sveobuhvatan dokument. Teza je trebala biti i cjelovita tako da je kandidat bio zamoljen da uključi i poglavlje o osnovnoj teoriji i opremi za upotrebu u skriningu raka dojke. Uz to, svi dobijeni rezultati istraživanja su uključeni. Sadržaji objavljenih naučnih radova su takođe uključeni u rukopis.

Teza sadrži sedam poglavlja.

Prvo poglavlje definiše rad na tezi.

Skrining raka dojke je u većini zemalja svijeta veliki zdravstveni problem za žene. Sonja objašnjava osnove bolesti, kao i kako se rak manifestuje u rendgenskim snimcima. Obično se vide razlike u kontrastu slika mekih tkiva (veličine> 2 mm) i sitnih kalcifikacija, koje se pod pravilnim rendgenskim uslovima mogu vidjeti i kada su reda veličine 100 μm. U drugom dijelu uvoda objašnjava se rendgenska tehnika. Iako postoji opsežna literatura u vezi s najnovijom digitalnom rendgenskom tehnikom, Sonja se odlučila da uglavnom koristi materijal nove knjige od strane Agencije za atomsku energiju (IAEA), 'Dijagnostička radiološka fizika', priručnik za nastavnike i studente 'D.R. Dance, S. Christofides, A.D.A. Maidment, I.D. McLean i K.H. Ng. Knjiga je objavljena 2014. godine.

Drugo poglavlje postavlja probleme koji će se rešavati u tezi i plan rada kako raditi na njima.

Poglavlje 3. Putem IAEA projekta RER 6004, Kliničkom centru je dostavljen kompletan set za testiranje mamografskih jedinica. Od posebne važnosti za ovaj rad je novi multimetar 'MagicMax' i antropomorfni fantom (vidi poglavlje 6).

Novi dozimetar je jedinstven, u smislu da u jednoj ekspoziciji simultano mjeri radijacioni izlaz cijevi, brzinu radijacionog izlaza, napon na cijevi, anoda/filter kombinaciju i poludebljinu (HVL). Ovaj jedinstveni pristup nameće potrebu istraživanja u smislu tačnosti uređaja sa naročitim akcentom na mjerenja HVL-a.

U prvom radu Sonja je provjerila koliko dobro eksponencijalna funkcija odgovara eksperimentalnim podacima, mjerenim jonizacionom komorom, koja ima svojstvo 'zlatnog standarda' za određivanje HVL-a. Uočeno je da se svi eksperimentalni podaci dobro fituju sa

eksponencijalnom funkcijom (koeficijenti korelacije su u većini slučajeva bili bolji od 99%), bez obzira na činjenicu da rendgenski zraci nisu mono-energetski.

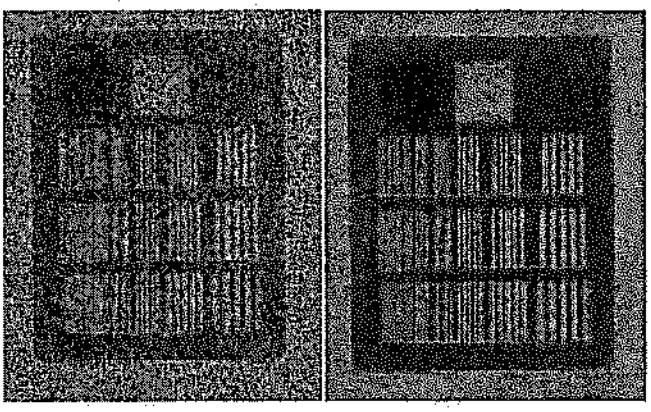
Drugi zadatak je bio procjena mjerne greške u određivanju HVL. Ocijenjeno je da je greška mjerenja HVL-a manje od 10% (obično je bila manja od 6%). Konačno je potvrđena metoda koja je predložena u mnogim protokolima za kontrolu kvalitete procjene HVL-a i sastoji se iz tri mjerenja.

U drugom dijelu poglavlja kandidat se bavio mjerenjima Magic-Max dozimetrom u jednoj ekspoziciji. Izvršena je provjera pouzdanosti kvaliteta x-zraka. Podaci izmjereni MagicMax-om su upoređivani sa mjerenjima jonizacionom komorom. Ova studija bila je dio šireg proučavanja koja je uključivala nekoliko drugih dozimetara (tekst se planira za štampu). U tezi se također provjerava i tačnost mjerenja napona cijevi. Test se temelji na pretpostavci da ako se isti kVp primijeni na različite anoda/filter kombinacije jednog te istog uređaja, izmjereni kVp bi trebali biti isti. Rezultati su potvrđivali pouzdanost mamografskih jedinica.

Razlike između direktnih mjerenja HVL –a sa MagicMax-om i mjerenja jonizacionom komorom nisu prelazile više od 0,02 mm Al. To je manje od standardne devijacije, pa su time i mjerenja MagicMax-om prihvatljiva. Zatim je primijenjena Robsonova metoda: u ovom pristupu HVL je procijenjivano u rasponu od 26 kVp do 32 kVp, sa mjerenjem HVL na 28 kVp. Za testirane anoda/filter kombinacije (zapravo Mo/Rh), odstupanja izmjerenih i ekstrapoliranih podataka su vrlo mala. Izvan raspona za kVp, koji je predložio Robson, tj. pri 24 kVp ili 34 kVp, odstupanja su veća, ali još uvek unutar granica, postavljenih bilo kojim QC protokolom.

Poglavlje 4. Digitalne slike su sa šumom. Sonja je radila na problemima naknadne obrade slike (post-procesiranje) u cilju redukcije šuma.

Oštrina slike mamografske jedinice se obično karakteriše njenom funkcijom širenja tačke (PSF) ili njenom modulacionom transfer funkcijom (MTF), u slučaju ako se jedinica ponaša kao linearno invarijantna na pomeraj. Nađen je efikasni metod za vraćanje oštrine digitalnih mamograma pomoću postupaka dekonvolucije. Nema više pojedinosti o metodi u tekstu (više pitanja se mogu postaviti tokom obrane teze), ali su rezultati ilustrirani:



Rekonstruisana testna slika korišćenjem metodologije 1 (levo) I metodologije 2 (desno)
Metod nije ilustrovan na kliničkim snimcima

Poglavlje 5. Ovo poglavlje opisuje prve korake prema primjeni cjelovitog protokola na mamogramskim jedinicama u Crnoj Gori, koja ima 15 film-skrin jedinica i jednu CR jedinicu. Kao testni protokoli korišćeni su Evropske smjernice za osiguranje kvalitete u skriningu raka dojke i IAEA protokol. U žiži ispitivanja je bila sigurnost (detaljno ispitivanje rendgenskih cijevi i x-snopova), doza pacijenata i kvalitet slike. Pošto su 14 od 15 jedinica film-skrin sistemi, senzitometrijska i denzitometrijska spitivanja su bila krucijalna.

AGD je raunata Dance-ovim metodom, što je takođe opisano u Evropskom protokolu za kontrolu kvaliteta fizičkih i tehničkih aspekata skrin-film mamografije. Doza je određivana korišćenjem standardnih kliničkih odabranih faktora izlaganja sa automatski kontrolisanom ekspozicijom (AEC) i PMMA 180 x 240 mm blokova, debljina od 20, 30, 40, 45, 50, 60 i 70 mm. Mjereni su vazdušna kerma na mestu upada zraka i HVL. Po prvi put se procjenjuju doza u mamografiji u Crnoj Gori na sistematski način. Dobro je poznato da su doze, određene na ovaj način tj., pomoću fantoma, dobri reprezenti doza koje primaju žene uz uslov da se koristi isti AEC. Rezultati su prikazani u Tabeli niže:

AGD vrednosti za 15 mamografskih jedinica, uporedo sa graničnim vrednostima

mammo jedinica	D_{20mm} PMMA (mGy)	D_{30mm} PMMA (mGy)	D_{40mm} PMMA (mGy)	D_{45mm} PMMA (mGy)	D_{50mm} PMMA (mGy)	D_{60mm} PMMA (mGy)	D_{70mm} PMMA (mGy)
1	0.91	2.35	3.84	4.39	5.02	5.47	6.7
2	0.76	1.18	1.83	2.09	2.46	3.62	5.56
3	0.68	1.07	1.63	1.96	2.32	3.51	4.91
4	0.56	0.85	1.32	1.49	1.79	2.66	3.91
5	0.54	0.85	1.36	1.63	1.98	2.86	4.32
6	0.77	1.07	1.49	1.55	1.71	2.21	3.96
7	0.45	0.71	1.16	1.36	1.67	2.48	3.75
8	0.48	0.73	1.15	1.21	1.49	2.11	2.91
9	0.48	0.42	0.51	0.64	0.66	0.64	0.75
10	0.75	1.16	1.81	2.21	2.64	3.81	6.02
11	0.92	1.46	2.33	2.81	3.86	4.27	7.74
12	0.53	0.82	1.41	1.7	2.07	3.5	6.36
13	0.87	1.21	1.78	2.13	2.49	3.64	5.38
14	0.8	1.26	1.97	2.42	2.91	4.21	6.56
15	0.42	0.65	1.02	1.19	1.43	2.07	2.78
Prihvatljivo	<1.0	<1,5	<2.0	<2.5	<3.0	<4.5	<6.5
Dostižno	<0.6	<1.0	<1.6	<2.0	<2.4	<3.6	<5.1

Podaci jedinice 9 nisu korišćeni, budući da su ocijenjeni kao neodgovarajući. Iz preostalih podataka izračunati su prvi dijagnostički referentni nivoi (DRL). Da bi se to postiglo, eksperimentalni podaci svih debljina su fitovani sa normalnom (Gaussovom) raspodjelom i ocjenom srednjih vrijednosti i standardnih odstupanja. Zatim je uzeta vrednost doze na 75% Gausove raspodjele za referentni nivo AGD-e. Vrijednosti su prikazane u sljedećoj Tabeli:

Predloženi DRL za skrining mamografiju u Crnoj Gori

Debljina PMMA (mm)	Equivalentna debljina dojke (mm)	Predloženi DRL (mGy)
20	21	0.8
30	32	1.4
40	45	2.1
45	53	2.5
50	60	3.0
60	75	3.9
70	90	6.0

Kvalitet slike sa aspekta optičke gustine nije na odgovarajućem nivou. U većini centara se ne koristi odgovarajuće procesiranje filma. Zaključak ovog rada je- urgentna optimizacija prakse.

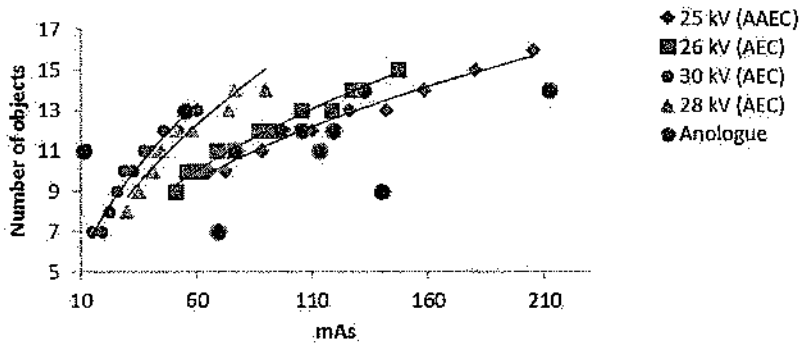
Poglavlje 6. Primijenjen je test protokol na CR mamografski sistem. To je omogućilo početak uvođenja protokola u osiguranju kvaliteta (QA) za digitalne jedinice u Kliničkom Centru u Crnoj Gori. Ciljevi tog dela rada su bili: (1) izgradnja testovnih procedura za QA u digitalnoj mamografiji sa novim testovnim uređajima, uključujući MagicMax multimetar (IBA, Nemačka) i tkivu ekvivalentan antropomorfni fantom Mammo AT (IBA, Nemačka) i (2) određivanje da li prvi digitalni CR sistem u Crnoj Gori zadovoljava današnje Evropske standarde.

Mamografski sistem koji se koristi u Kliničkom centru Crne Gore se sastoji od različitih komponenti, koji zajedno čine cjeloviti lanac za snimanje: Planmed Sophie mamografski rendgenski uređaj, Konica Minolta CR mamografske ploče za snimanje RP-6M, čitač Konica Minolta Regius 190 CR, Kodak Dry View 6800 laserski pisač, Rogan View Pro-X radna stanica i ekran za gledanje snimaka. Testovi su uglavnom izvedeni iz Evrropskog protokola i uključuju: radijacioni izlaz cijevi (μGy / mAs), brzinu radijacionog izlaza (mGy/s), reproducibilnost i tačnost napona cijevi, poludebljinu, reproducibilnost i tačnost AEC sistema, kontrole koraka ekspozicije, funkciju odziva receptora, kvalitet slike i test stabilnosti pisača. Prosječna glandularna doza je određivana i pikazana u poglavlju 5. Rezultati su sažeti u naučnom članku i predstavljeni na Konferenciji u Varni 2014. godine. U tom članku je glavni fokus bio na tkivu ekvivalentnom antropomorfnom fantomu Mammo AT (IBA). Pošto ovaj antropomorfni fantom nije imao nikakvih ograničavajućih vrijednosti u smislu neprihvatljivosti, bio je primijenjen na svim film-skrin jedinicama kako bi se dobili prvi referentni nivoi doza. Tada su se novi digitalni podaci mogli porediti sa DRL. Ovo je u skladu s pristupom koji je usvojen za CDMAM fantom pri prijelazu s film-skrin jedinica na digitalno snimanje. Međutim, u ovom radu je upozoreno da kvalitet film-skrin jedinica nije verifikovan. Ipak, mišljena smo da sa ovim fantomom možemo garantovati da kvalitet digitalnih sistema neće biti slabiji od trenutne prakse u zemlji s film-skrin sistemima, ako bi ista količina detalja na fantomu bila vidljiva. Pošto CR sistem može da funkcioniše na više doznih nivoa, sve doze kandidati su bili testirani i upoređivani sa rezultatima film-skrin jedinica sa aspekta vidljivih detalja.

Kako bi se dobile referentne vrijednosti film-skrin jedinica, sniman je fantom na 11 konvencionalnih mjesta, testiranih od strane ovlašćenih tehničkih servisa Crne Gore. Na tri

Siemens jedinice, fantom je bio izlagan manuelno dok nije dobijena odgovarajuća optička gustina. Na ostalim konvencionalnim jedinicama (Planmed Sophie Classic - Finska) korišćen je AEC način rada. Na konvencionalnim sistemima broj vidljivih objekata je bio između 7 i 14. Ocijenjeno je da je granični broj vidljivih detalja od 7 ÷9 sumnjiv za performansu sistema i predlaženo je kao minimalni kriterij '11 objekata koji se mogu detektovati'.

Fantom se tada izlagao x-snopu CR jedinice, menjajući korak od -5 do +5 s AEC (fiksnim kV i Mo-Mo) i AAEC (automatski izbor anode/flter i kVp). U kliničkoj praksi, korak 0 je bio u upotrebi. Može se vidjeti da je u kliničkom režimu sa AEC i korakom 0 ispunjen minimalni kriterij od 11 objekata za sve napone cijevi ispod 30 kVp. To nije bio slučaj pri naponu od 30 kV, i razloge za to vrijedi istražiti.



Kvalitet snimka dobijen sa IBA fantomom za sve vrijednosti kVp i uzastopnim AEC koracima od -5 to +5. Analogni sistemi su prikazani sa crvenim krugovima. Preporučena vrijednost: 11 objekata.

Rezultati istraživanja su pokazali da je moguće postići QA na digitalnom CR mamografu, korišćenjem IBA fantoma. Ovaj projekt je poslužio, istovremeno i za istraživanje i za obuku. Zaključeno je da:

(1) su svi mjereni parametri unutar opsega, opisanog u Evropskim protokolima, osim napona cijevi koji je odstupao više od ± 1kV. Automatsko određivanje HVL-a je bilo zadovoljavajuće. Prosječna glandularna doza je bila od 0,66 do 7,02 mGy za debljine PMMA od 20 do 70mm i bila je u skladu sa podacima iz literature.

(2) Ocjena kvaliteta slike koja je dobijena tkivu ekvivalentnim antropomorfnim fantomom Mammo AT za CR sistem je bila slična rezultatima dobijenim iz konvencionalne mamografije s filmom.

Poglavlje 7. Urađena su prva istraživanja QC na nedavno instaliranom sistemu digitalne tomosinteze grudi (DBT) u Crnoj Gori. U ovom posljednjem poglavlju sprovedeno je ispitivanje prihvatljivosti puštanja sistema u rad, koristeći preliminarni protokol EUREF tima. Svi su testovi izvedeni zajedno s profesorom Nicholasom Marshallom (KU Leuven). Izvještaj je uključen i komentarisan u rukopisu. Rezultati su bili u skladu s rezultatima na drugim Hologic sistemima koje su ranije testirali drugi timovi. Sonja sada može periodično reprodukovati ta mjerenja.

III Mišljenje i predlog

Visok kvalitet QA i QC u mamografiji je od izuzetne važnosti za rano otkrivanje raka dojke. Na početku rada na ovoj tezi u Crnoj Gori nije bio razvijen QC mamografskih sistema. Sa mjerenjima sprovedenim u ovoj tezi, nivo QC je znatno povećan. Započelo se s primjenom smjernica EU i IAEA za QC u mamografiji i Sonja je dobila prve rezultate.

Glavni naučni doprinosi ove teze su procjena nesigurnosti određivanja vrijednosti poludebljine u mamografiji; provjera automatiziranih mjerenja filterima s novim MagicMax detektorom i potvrđivanje Robsonove parametrizacije za ocjenjivanje svih HVL-ova iz jednog mjerenja na 28 kVp. Sljedeći doprinos je predložena rekonstrukcija snimka bazirana na Wiener-ovim filterima. Prvi put su bili primijenjeni protokoli QC na film-skrin, CR i DBT jedinicama. Predložen je prvi crnogorski DRL za mamografiju. Na temelju svih iskustva dobijenih QC-om na film-skrin, CR i DR s tomosintezom, Sonja je sada dobro pripremljena za globalno izvođenje QC-a u screeningu dojke, korišćenjem najnovijih Evropskih i IAEA smjernica. Ovo je glavno dostignuće i izražavamo nadu da će se ova stručnost koristiti u zemlji.

Komisija predlaže Vijeću Prirodno-matematičkog fakulteta i Senatu Univerziteta Crne Gore da prihvati pozitivnu ocjenu ponuđenog teksta i odobre javnu odbranu disertacije kandidatu

mr Sonji Ivanović

pod naslovom

„Unapređenje kontrole kvaliteta i osiguranje kvaliteta (QA i QC) u skriningu i dijagnostičkoj mamografiji u Crnoj Gori“.

Podgorica, 27. Decembar 2017.

KOMISIJA:

dr Hilde Bosmans (vanredni profesor Medicinskog fakulteta u Luvenu),

dr Olivera Ciraj Bjelajac (vanredni profesor elektrotehničkog fakulteta u Beogradu),

dr Slavoljub Mijović (redovni profesor Prirodno-matematičkog fakulteta u Podgorici),

dr Mara Šćepanović (redovni profesor Prirodno-matematičkog fakulteta u Podgorici),

dr Mira Vučeljić (redovni profesor Prirodno-matematičkog fakulteta u Podgorici)

TO THE COUNCIL OF THE FACULTY OF SCIENCES AND MATHEMATICS AND THE SENATE OF UNIVERSITY OF MONTENEGRO IN PODGORICA

SUBJECT: Evaluation of the Doctoral dissertation of MSc Sonje Ivanović

At the session of the Senate of the University of Montenegro, held on 16.10.2017., the Commission was appointed with the members: Dr Hilde Bosmans (associate professor of the Faculty of Medicine in Leuven), Dr Olivera Ciraj Bjelajac (associate professor of the Faculty of Electrical Engineering in Belgrade), Dr Slavoljub Mijović (full professor of the Faculty of Sciences and Mathematics in Podgorica), Dr Mara Šćepanović (full professor of the Faculty of Sciences and Mathematics in Podgorica), Dr Mira Vučeljić (full professor of the Faculty of Sciences and Mathematics in Podgorica), with the task of reviewing and evaluating the doctoral dissertation under the title "Improving QA/QC in Mammography Screening and Breast Diagnosis in Montenegro" of the candidate, MSc Sonja Ivanović.

The Commission reviewed the text of the dissertation and submits to the Council and the Senate the following

REPORT

I The subject and goal of the doctoral dissertation

Breast cancer screening is in most countries of the world a big health problem for women. The overall objective of this thesis is to investigate and improve methods for evaluation of average glandular dose (AGD) and image quality in mammography and to correlate physical and technical quality to clinical image quality.

The specific objectives were:

- evaluation of the technical situation of the Montenegrin mammography systems;
- improvement of methods for evaluation of average glandular dose (AGD) and image quality;
- establishment of national dose reference levels from data acquired according international standards;
- a verification of reliability of automated filter measurements with the MagicMax multimeter.

In addition, the new tomosynthesis technology had to be investigated by means of technical tests.

II The structure and results of the dissertation

Sonja's thesis is the first in its kind in Montenegro and therefore it was opted to make it a comprehensive document. The document had to be self-containing and she was asked to include also a chapter on the basic theory and equipment for use in breast cancer screening. Next to this, all the research efforts have to be reported too. It was chosen to collect the published scientific papers and include them in the manuscript.

The thesis of Sonja consists of 7 chapters.

The first chapter situates the work.

Breast cancer screening is in most countries of the world a big health problem for women. Sonja explains the basics of the disease, as well as how a cancer shows up in x-ray images. It is usually distinguished between soft tissue masses (with sizes > 2mm) and tiny calcifications which, under proper x-ray conditions, can be visible from sizes as small as 100 μm. In the second part of the introduction, she explains the x-ray technology. An extensive literature search regarding the best up-to-date texts on digital x-ray technology made Sonja decide to mainly use the material of a new text book by the IAEA, 'Diagnostic Radiology Physics A Handbook for Teachers and Students' by D.R. Dance, S. Christofides, A.D.A. Maidment, I.D. McLean and K.H. Ng. The book was published in 2014.

The second chapter situates the thesis: the problem to be solved was defined and the traject on how to work at it is explained.

Chapter 3. Via the RER 6004 project with the IAEA, a complete test set of equipment was provided to the center. Of importance in this work is the new multimeter 'MagicMax' and an anthropomorphic phantom (see chapter 6).

The new dosemeter is unique, in a sense that it allowed to measure in a single step tube output, tube output rate, tube voltage, anode/filter and HVL. This unique output triggered an investigation on the accuracy of the device and on HVL measurements in particular.

In a first paper, Sonja has checked how well an exponential function fits the experimental data, from ionisation chamber measurements that act as gold standard, to obtain the HVL. It was observed that all experimental data fitted well to an exponential function (correlation coefficients

were in most cases better than 99%), notwithstanding the fact that x-ray beams are not mono energetic.

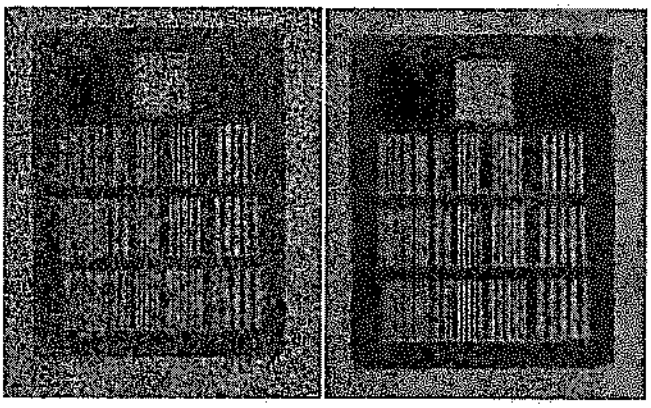
The second task was the estimation of the uncertainty on HVL determination: the uncertainty of HVL was found to be less than 10% (usually less than 6%). Finally the method proposed in many QC protocols to estimate the HVL from 3 measurements was reconfirmed.

The second part of the chapter dealt with the one-stop-shop measurements of the Magic Max dosimeter. It was investigated whether its beam quality measurements are trustworthy. Magic Max data were compared to measurements with ionization chambers. This study was part of a larger study that included several other dosimeters (text to be submitted). In the thesis, also the tube voltage measurement accuracy is tested too. The test was based on the assumption that if the same kVp is applied to different anode/filters of a single device, the measured kVp should be the same. The results were re-assuring for the device.

The difference between the direct HVL measurements of Magic Max and ionization measurements do not exceed more than 0.02 mm Al. This is smaller than the standard deviation, and is therefore judged acceptable. Next, Robson's method was applied: in this approach, the HVL in the range 26kVp – 32 kVp is estimated from the HVL at 28kVp. For the tested anode/filters (namely Mo/Rh), the deviations between the measured and the extrapolated data are very small. Outside the kVp range proposed by Robson, i.e. at 24kVp or 34 kVp, the deviations are larger but within limiting values set by any QC protocol.

Chapter 4. Digital images are noisy. Sonja has worked at a post processing procedures to reduce the appearance of the noise.

The sharpness of an imaging system is usually characterized by its Point Spread Function (PSF) or its Fourier transformation MTF if the imaging system is linear shift invariant. The thesis reports on a method to restore the sharpness of digital mammograms using deconvolution procedures. There aren't any more details about the method in the text (more questions may be asked during the defense of the work), but the results are illustrated:



The restored images by using methodology 1(left) and methodology 2 (right)
The method is not illustrated in clinical images.

Chapter 5. This chapter describes the first steps toward applying the complete protocol on Montenegrin systems. The country has 15 film-screen units and 1 CR unit. As a test protocol, the European Guidelines for Quality Assurance in breast cancer screening and the IAEA protocol, were implemented. There was a focus on safety (by testing the x-ray tube and beam in detail), patient dose and image quality. As 14 / 15 systems use film-screen, sensitometry and densitometry were crucial.

The average glandular dose (AGD) were calculated with Dance's method, as also described in the European protocol for the quality control of the physical and technical aspects of screen – film mammography. The dose was determined using the standard clinically selected exposure factors under Automatic Exposure Control (AEC) and for PMMA blocks of 180 x 240 mm with thicknesses of 20, 30, 40, 45, 50, 60 and 70 mm. Incident air kerma and HVL were measured. For the first time, mammography doses have been estimated for Montenegrin systems. It is well known that these phantom determined doses are representative for the women, if, of course, the same AEC is used. Data are shown in the next Table:

AGD values for 15 mammo units, compared to limiting values

mammo unit	D_{20mm} PMMA (mGy)	D_{30mm} PMMA (mGy)	D_{40mm} PMMA (mGy)	D_{45mm} PMMA (mGy)	D_{50mm} PMMA (mGy)	D_{60mm} PMMA (mGy)	D_{70mm} PMMA (mGy)
1	0.91	2,35	3.84	4.39	5.02	5.47	6.7
2	0.76	1.18	1.83	2.09	2.46	3.62	5.56
3	0.68	1.07	1.63	1.96	2.32	3.51	4.91
4	0.56	0.85	1.32	1.49	1.79	2.66	3.91
5	0.54	0.85	1.36	1.63	1.98	2.86	4.32
6	0.77	1.07	1.49	1.55	1.71	2.21	3.96
7	0.45	0.71	1.16	1.36	1.67	2.48	3.75
8	0.48	0.73	1.15	1.21	1.49	2.11	2.91
9	0.48	0.42	0.51	0.64	0.66	0.64	0.75
10	0.75	1.16	1.81	2.21	2.64	3.81	6.02
11	0.92	1.46	2.33	2.81	3.86	4.27	7.74
12	0.53	0.82	1.41	1.7	2.07	3.5	6.36
13	0.87	1.21	1.78	2.13	2.49	3.64	5.38
14	0.8	1.26	1.97	2.42	2.91	4.21	6.56
15	0.42	0.65	1.02	1.19	1.43	2.07	2.78
acceptable	<1.0	<1,5	<2.0	<2.5	<3.0	<4.5	<6.5
achievable	<0.6	<1.0	<1.6	<2.0	<2.4	<3.6	<5.1

Data of system 9 were not used, as these data were not judged appropriate. From the remaining data, a first Diagnostic Reference level (DRL) was calculated. To do so, the experimental data of all thicknesses were fitted with a normal (Gaussian) distribution and estimation for mean values and standard deviation was done. Then the 75 percentile for the AGD was obtained. The values are shown in the next Table:

Proposed DRL for screening mammography in Montenegro

Thickness PMMA (mm)	Equivalent Breast Thickness (mm)	Proposed DRL (mGy)
20	21	0.8
30	32	1.4
40	45	2.1
45	53	2.5
50	60	3.0
60	75	3.9
70	90	6.0

Image quality in terms of optical density was not on a good level. Most centers do not use appropriate film processing. The conclusion of the work was that optimization of practice should be organized urgently.

Chapter 6 applied the test protocol on a CR Mammography system. It allowed to make a start with a protocol for the quality assurance of digital mammography in the clinical centre of Montenegro. The purposes of this part of the work were (1) to work out a test procedure for Quality Assurance (QA) in digital mammography with the new test equipment, including the MagicMax multimeter (IBA, Germany) and the anthropomorphic tissue equivalent phantom Mammo AT (IBA, Germany), and (2) to determine whether a first digital CR system in Montenegro meets the current European standards.

The mammography system used in the Clinical Centre of Montenegro consists of different components, forming all together the complete imaging chain: a Planmed Sophie mammographic x-ray unit, Konica Minolta CR mammography imaging plates RP-6M, a Konica Minolta Regius 190 CR reader, a Kodak Dry View 6800 Laser printer, a Rogan View Pro-X workstation and viewing boxes. The tests were mainly derived from the European protocol and include: tube output (μGy/mAs), output rate (mGy/s), reproducibility and accuracy of tube voltage, half value layer, reproducibility and accuracy of the AEC system, exposure control steps, image receptor's response function, image quality and printer stability test. The average glandular dose was measured and reported in chapter 5. The results are summarized in a scientific paper, presented at the Varna Conference in 2014. In this text, a major focus was on the anthropomorphic tissue equivalent phantom Mammo AT (IBA). Hence, this anthropomorphic phantom did not have any limiting values that could guide the decision of acceptability. Therefore, the phantom was applied on all the film-screen systems to obtain a first reference level, to which the new digital data could be compared. This is in line with the approach that had been adopted for the CDMAM phantom at the transition from film screen to digital imaging. In present study, it was warned however that the quality of the screen film systems was not guaranteed. Nevertheless, the phantom was thought to be able to guarantee that the quality of a digital system would not be lower than the current practice in the country with film-screen if at the least the same amount of test inserts would be visible. As the CR system could be operated with several dose levels, all candidate dose levels were tested and compared to the scores of film-screen.

In order to obtain reference values from film-screen systems, the phantom was taken to 11 conventional sites, tested by the Authorized Technical Services of Montenegro according. On the three Siemens units, the phantom was exposed manually, until proper optical density was obtained. On the other conventional units (Planmed Sophie Classic – Finland), the AEC mode was used. The conventional systems show between 7 and 14 objects. We consider the values of system 7 and 9 as outliers, or at least suspicious for poorer performance and propose as a minimal criterium '11 objects detectable'.

The phantom was then exposed by the CR unit using the steps from -5 to +5 with AEC (fixed kV and Mo-Mo) and AAEC (automatic choice of anode/filter and kVp). In clinical practice, step 0 was in use. It can be seen that at the clinical AEC step 0 for all tube voltages below 30kVp, the minimal criterium of 11 objects is met. This is not the case for the 30kV setting, an issue worth exploring.

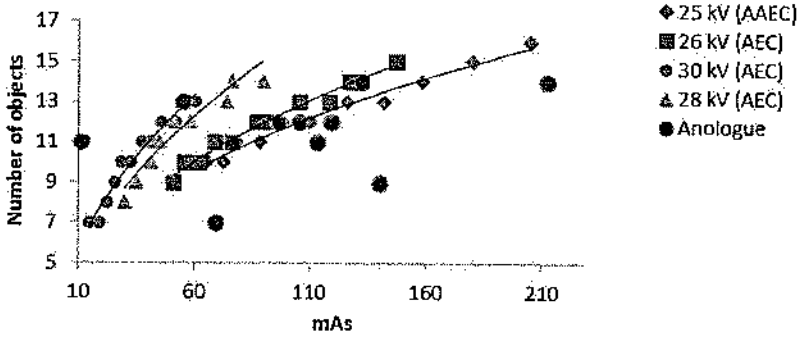


Image quality as obtained with the IBA phantom for all kVps and successive AEC steps from -5 to +5. Analogue systems are shown with red circles. Limiting value: 11 objects.

The main findings are that QA on digital CR mammography is feasible in Montenegro and there is a first limit available for use with the IBA phantom. This project served both training and research purposes. It was concluded that:

(1) All measured parameters are within the range described in European protocols except for the tube voltage which deviated more than ±1kV. The automatic determination of the HVL was satisfactorily. Average glandular dose ranged from 0.66 to 7.02mGy for PMMA thicknesses from 20 to 70mm, and is in accordance with literature data.

(2)The image quality score as obtained with the Anthropomorphic tissue equivalent phantom Mammo AT for the CR system was similar to the scores obtained from conventional screen-film mammography.

Chapter 7 deals with the first exploration of QC on the newly installed Digital Breast Tomosynthesis (DBT) system in Montenegro. In this final chapter, an acceptance test was performed, using a preliminary protocol by the euref team. All the tests were performed together with prof Nicholas Marshall (KU Leuven). The report is included and commented in the manuscript. The results were conform to results on other Hologic systems tested earlier by other teams. Sonja can now reproduce these measurements periodically.

III The opinion and suggestion

High quality of QA and QC in mammography is of utmost importance for early detection of breast cancer. At the start of this thesis, QC of mammography systems was not developed in Montenegro. With the measurements conducted in this thesis, the level of QC has significantly increased. A start was made with the implementation of EU and IAEA guidelines for QC in mammography and Sonja got the first results.

The main scientific contributions of this thesis are the assessment of uncertainties on half value layer determination in mammography; the validation of automated filter measurements with the new MagicMax instrumentation and validation of Robson's parameterization to retrieve all HVLs from a single measurement at 28kVp. Next, a quality restoration procedure based on Wiener filters was proposed. Next, QC protocols have been applied on the current film-screen systems, on the CR system and on the combined DR – tomosynthesis system. The first Montenegrin DRL for mammography was proposed. Based on all experience collected with QC of film-screen systems, CR and DR with tomosynthesis, Sonja is now well prepared for a global roll out of QC in breast cancer screening using the latest European and IAEA guidelines. This is a major achievement, and we express the hope that this expertise is being used in the country today.

The Commission proposes to the Council of the Faculty of Natural Sciences and Mathematics and the Senate of the University of Montenegro to accept a positive evaluation of the offered text and to approve the public defense of the dissertation of the candidate

MSc Sonja Ivanović

under the title

"Improving QA/QC in Mammography Screening and Breast Diagnosis in Montenegro"

Podgorica, December 25, 2017.

THE COMISSION:

Dr Hilde Bosmans (associate professor of the Faculty of Medicine in Leuven),

Dr Olivera Ciraj Bjelajac (associate professor of the Faculty of Electrical Engineering in Belgrade),

Dr Slavoljub Mijović (full professor of the Faculty of Sciences and Mathematics in Podgorica),

Dr Mara Šćepanović (full professor of the Faculty of Sciences and Mathematics in Podgorica),

Dr Mira Vučeljić (full professor of the Faculty of Sciences and Mathematics in Podgorica)

VIJESTI 28-12-2017

OBAVJEŠTENJE

Doktorska disertacija Mr Sonje Ivanović, pod nazivom "Unapređenje osiguranja i kontrole kvaliteta dijagnostike i skrining mamografije u Crnoj Gori", kao i Izvještaj Komisije o ocjeni i pregledu doktorske disertacije stavljaju na uvid i ocjenu javnosti u Biblioteci Univerziteta Crne Gore u vremenu od 9 do 15 časova u Biblioteci Univerziteta Crne Gore u periodu od 30 dana, od dana objavljivanja obavještenja.

Komisija za ocjenu i pregled doktorske disertacije:

1. **Dr Slavoljub Mijović**, redovni profesor Prirodno-matematičkog fakulteta u Podgorici - mentor;
2. **Dr Hilde Bosman**, vanredni profesor Katoličkog Univerziteta Luven Belgija;
3. **Dr Olivera Ciraj Bjelac**, vanredni profesor, Elektrotehničkog fakulteta, Univerziteta u Beogradu;
4. **Dr Mara Šćepanović**, redovni profesor Prirodno-matematičkog fakulteta u Podgorici;
5. **Dr Mira Vučeljić**, redovni profesor, Prirodno-matematičkog fakulteta u Podgorici.

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N/r dekanu

Prof. dr Predragu Miranoviću

Poštovani profesore Miranoviću,

Vraćamo doktorsku disertaciju **„Unapređenje osiguranja i kontrole kvaliteta dijagnostike i skrining mamografije u Crnoj Gori“,** sa Izvještajem Komisije za ocjenu doktorske disertacije, kandidatkinje mr Sonje Ivanović, koja je, u skladu sa članom 42 stav 3 Pravila doktorskih studija, dostavljena **Centralnoj univerzitetskoj biblioteci** dana 29. 12. 2017. godine, na uvid i ocjenu javnosti,.

Na gore pomenutu doktorsku disertaciju nije bilo primjedbi javnosti u predviđenom roku od 30 dana.

Nakon odbrane navedene doktorske disertacije, potrebno je dostaviti konačan primjerak disertacije u štampanoj i elektronskoj formi. Štampana i elektronska verzija disertacije treba da sadrži: izjavu o autorstvu, izjavu o istovjetnosti štampane i elektronske verzije doktorskog rada i izjavu o korišćenju. Sve moraju biti popunjene i potpisane od strane doktoranda.

S poštovanjem,

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Na osnovu člana 75 stav 2 Zakona o visokom obrazovanju (Sl.list RCG br. 60/03.) i člana 19 Statuta Univerziteta Crne Gore, Senat Univerziteta Crne Gore, na sjednici održanoj 28.04.2005. godine, donio je

O D L U K U
O IZBORU U ZVANJE

Dr SLAVOLJUB MIJOVIĆ bira se u akademsko zvanje redovni profesor Univerziteta Crne Gore za predmete: Fizika jonizovanih gasova **na Prirodno-matematičkom fakultetu** u Podgorici i Fizika na nematičnim fakultetima.

REKTOR

Prof. dr Ljubiša Stanković

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OBRAZOVANJE

1994-1997	Centralno Evropski Univerzitet, Budimpešta. Master MSc Program u Zaštiti životne okoline i politike
1989-1993	Univerzitet u Beogradu, Beograd Doktorske studije PhD Program u Fizici jonizovanog gasa
1984-1989	Univerzitet u Beogradu, Beograd Magistarske studije MSc Program u Fizici jonizovanog gasa
1976-1982	Univerzitet u Beogradu, Beograd Elektrotehnički fakultet, odsek tehničke fizike, smer nuklearne fizike

SPECIJALIZACIJE

1989-1991	Moskovski Državni Univezitet, Rusija, Fizički fakultet, katedra fizičke elektronike 2.5 godina
1995.	UCLA-Univerzitet Kalifornije Los Anđeles 2 meseca na Odseku plazma fizike
1996.	Ecologia-Internationalna Organizacija, Pensilvanija 1 mesec

RADNO, PREDAVAČKO I ISTRAŽIVAČKO ISKUSTVO

1983-1993	Asistent na Univerzitetu Crne Gore , Prirodno-matematički fakultet, Odsek za fiziku, za predmete Opšta i Atomska fizika.
1993-1995	Docent na Univerzitetu Crne Gore , Prirodno-matematički fakultet, Odsek za fiziku, za predmete Uvod u fiziku eksperimenta i Fizike jonizovanog gasa. Rukovodilac projekta: Nekorektni problem u dijagnostici plazmenih parametara.
1995-1999:	Docent na Univerzitetu u Prištini-Jugoslavija Odsek za fiziku, za predmete: Atomska fizika i Fizika Lasera. Uključen u postdiplomske studije Univerziteta u Nišu u grupi eksperimentalne fizike jonizovanih gasova za kurs: Dijagnostičke metode u plazmi.
1996-1999 2002-2005	Šef Odseka za Fiziku u Prištini (Kosovo i Metohija). Prodekan za naučno-istraživački rad i finansije prirodno-matematičkog fakulteta u Podgorici
Projekti:	Rukovodilac naučnih projekata: Nacionalni projekat Crne Gore o:•Spektroskopija plazme, Fizika plazme, Fizika jonizovanih gasova i jonizujućeg zračenja; Federalni projekat Jugoslavije:• Nekorektni problemi u dijagnostici plazme Internacionalni projekat: •*Solar Water Heating Analysis for Yugoslavia* Internacionalni projekatt •*Integrated Monitoring of Skadar Lake* Internacionalni projekat •*IAEA Improving screening mammography in Montenegro* Lokalni Koordinator CEEPUS mreža: *Aplikacije i dijagnostika Plazme; Procesiranje slika.* Predavač po pozivu u Austriji, Češkoj republici, Slovačkoj i Mađarskoj.
1999-danas 2007- danas	Profesor na Univerzitetu Crne Gore Rukovodilac Centra za životnu sredinu i šef grupe za osiguranje i kontrolu kvaliteta u zaštiti od jonizujućeg zračenja; Član nacionalnog Savetodavnog tela za pitanja zaštite od zračenja.
Ostalo:	Govori srpski, ruski, engleski i malo nemački. Hobi: tenis i šah.

Bibliografija prof. dr Slavoljuba Mijović

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O D L U K U
O IZBORU U ZVANJE

Dr MARA **ŠĆEPANOVIĆ** bira se u akademsko zvanje **redovni profesor** Univerziteta Crne Gore za predmete: Atomska fizika, **na Prirodno-matematičkom fakultetu** i Fizika, na nematičnim fakultetima.

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Podaci o radnim mjestima i izborima u zvanje

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Б е о г р а д

На основу члана 22. става 2. члана 70. став 7. Закона о научноистраживачкој делатности ("Службени гласник Републике Србије", број 110/05 и 50/06 – исправка и 18/10), члана 2. става 1. и 2. тачке 1 – 4.(прилози) и члана 38. Правилника о поступку и начину вредновања и квантитативном исказивању научноистраживачких резултата истраживача ("Службени гласник Републике Србије", број 38/08) и захтева који је поднео

Институт за нуклеарне науке "Винча" у Београду

Комисија за стицање научних звања на седници одржаној 16.07.2014. године, донела је

ОДЛУКУ
О СТИЦАЊУ НАУЧНОГ ЗВАЊА

Др Оливера Цирај Бјелац
стиче научно звање
Научни саветник

у области природно-математичких наука - физика

О Б Р А З Л О Ж Е Њ Е

Институт за нуклеарне науке "Винча" у Београду

утврдио је предлог број 446/5 од 20.03.2014. године на седници научног већа Института и поднео захтев Комисији за стицање научних звања број 446/18 од 28.03.2014. године за доношење одлуке о испуњености услова за стицање научног звања ***Научни саветник***.

Комисија за стицање научних звања је по претходно прибављеном позитивном мишљењу Матичног научног одбора за физику на седници одржаној 16.07.2014. године размотрила захтев и утврдила да именована испуњава услове из члана 70. став 7. Закона о научноистраживачкој делатности ("Службени гласник Републике Србије", број 110/05 и 50/06 – исправка и 18/10), члана 2. става 1. и 2. тачке 1 – 4.(прилози) и члана 38. Правилника о поступку и начину вредновања и квантитативном исказивању научноистраживачких резултата истраживача ("Службени гласник Републике Србије", број 38/08) за стицање научног звања ***Научни саветник***, па је одлучила као у изреци ове одлуке.

Доношењем ове одлуке именована стиче сва права која јој на основу ње по закону припадају.

Одлуку доставити подносиоцу захтева, именованој и архиви Министарства просвете, науке и технолошког развоја у Београду.

ПРЕДСЕДНИК КОМИСИЈЕ
Др Станислава Стошић-Грујичић,
научни саветник

МИНИСТАР
Др Срђан Вербић

УНИВЕРЗИТЕТ У БЕОГРАДУ

Адреса: Студентски трг 1, 11000 Београд, Република Србија
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ВЕЋЕ НАУЧНИХ ОБЛАСТИ
ТЕХНИЧКИХ НАУКА

Београд, 17.09.2012.
02 Број: 06-20264/54-12
ТК

На основу чл. 65. ст. 2. Закона о високом образовању ("Службени гласник РС", број 76/05, 97/08, 100/07-аутентично тумачење и 44/10), чл. 47. ст. 5. тач. 1. Статута Универзитета у Београду ("Гласник Универзитета у Београду", број 162/11-пречишћени текст), чл. 13. ст. 1. Правилника о већима научних области на Универзитету у Београду ("Гласник Универзитета у Београду", број 134/07, 150/09, 158/11 и 164/11), чл. 21. ст. 1. тач. 1. Правилника о начину и поступку стицања звања и заснивања радног односа наставника Универзитета у Београду ("Гласник Универзитета у Београду", број 142/08, 150/09 и 160/11) и Критеријума за стицање звања наставника на Универзитету у Београду ("Гласник Универзитета у Београду", број 140/08, 144/08, 160/11, 161/11 и 165/11), а на предлог Изборног већа Електротехничког факултета, број: 969/4 од 03.07.2012. године, Веће научних области техничких наука, на седници одржаној 17.09.2012. године, донело је

О Д Л У К У

БИРА СЕ др Оливера Цирај-Бјелац у звање ванредног професора на Универзитету у Београду – Електротехнички факултет за ужу научну област Нуклеарна техника.

О б р а з л о ж е њ е

Електротехнички факултет је дана 25.04.2012. године у листу "Послови" објавио конкурс за избор у звање ванредног професора за ужу научну област Нуклеарна техника, због истека изборног периода.

Извештај Комисије за припрему извештаја о пријављеним кандидатима стављен је на увид јавности дана 14.06.2012. године преко библиотеке факултета.

На основу предлога Комисије за припрему извештаја о пријављеним кандидатима, Изборно веће Електротехничког факултета, на седници одржаној дана 03.07.2012. године, донело је одлуку о утврђивању предлога да се кандидат др Оливера Цирај-Бјелац изабере у звање ванредног професора.

Електротехнички факултет је дана 11.07.2012. године доставио Универзитету комплетан захтев за избор у звање на прописаним обрасцима.

Универзитет је комплетну документацију коју је доставио факултет ставио на web страницу Универзитета дана 10.09.2012. године.

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[17.] **S. Mijovic** *Ekonomska analiza solarnog grejanja vode u Jugoslaviji* ECOLOGICA; Winter, 1997.

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Веће научних области техничких наука, на седници одржаној дана 17. септембра 2012. године разматрало је захтев Електротехничког факултета и утврдило да кандидат испуњава услове прописане чл. 64. и 65. Закона о високом образовању, чл. 124. Статута Универзитета у Београду, као и услове прописане Критеријумима за стицање звања наставника на Универзитету у Београду, па је донета одлука као у изреци.

ПРЕДСЕДНИК ВЕЋА

Проф. др Милосав Огњановић

Доставити:
- Факултету (2)
- архиви Универзитета

Др Оливера Цирај-Бјелац, ванредни професор
Катедра за микроелектронику и техничку физику Електротехничког факултета у Београду

А. БИОГРАФСКИ И АКАДЕМСКИ ПОДАЦИ О КАНДИДАТУ

Оливера Цирај-Бјелац је рођена 3.6.1972. у Инђији, где је завршила основну школу и гимназију, чиме је стекла звање математичко-програмерског сарадника. Природно-математички факултет у Новом Саду уписала је школске 1991/92. године а дипломирала 1995. године са просечном оценом 9,47 и стекла звање: дипломирани физичар. Последипломске студије из Медицинске физике на Универзитету у Новом Саду уписала је школске 1996/97 године. Магистарски рад под насловом: "Процена степена изложености медицинског тима у контрастним техникама рендгендијагностике" одбранила је 2000. године и тиме стекла академско звање магистра Медицинске физике, интердисциплинарне области физичких и медицинскх наука. Докторску дисертацију под називом: "Процена изложености и могућности за смањење пацијентних доза у дијагностичкој радиологији" одбранила је 2005. године на Универзитет у Новом Саду.

Од 1996. до 1999. била је запослена у Институту за медицину рада и радиолошку заштиту Клиничког центра Србије, у Одељењу за контролу извора зрачења и личну дозиметрију. Од 1999. запослена је у Лабораторији за заштиту од зрачења и заштиту животне средине, Института за нуклеарне науке "Винча", прво у звању истраживач-сарадник (1999-2006), а касније у звању начни сарадник (2006-2010). Од 2010. до 2014. године Оливера Цирај Бјелац радила као виши научни сарадник у Лабораторији за заштиту од зрачења и заштиту животне средине Института за нуклеарне науке Винча, а 2014. године је стекла звање хаучног саветника. Од 2007. године у звању доцента а од 2012. године у звању ванредног професора на Катедри за микроелектронику и техничку физику учествује у настави на основним и последипломским студијама на Електротехничком факултету Универзитета у Београду.

Активан је учесник неколико међународних и националних научних пројеката из области радијационе физике и заштите од зрачења. Била је члан радне групе 78 Међународне Комисије за заштиту од зрачења (ICRP) за израду публикације ICRP 117 „Radiological Protection in Fluoroscopically Guided Procedures outside the Imaging Department" и учествовала је и у изради и рецензији документа Међународне Агенције за Атомску Енергију (IAEA) на тему заштите од зрачења у медицини и развоју тренинг пакета из исте области. Члан је Комисије за електричне уређаје у медицини Института за стандардизацију Србије, Друштва за медицинску физику Србије и Друштва за заштиту од зрачења Србије и Црне Горе, чији је председник била у три мандата, од 2007. до 2013. године.

Бави се проблемима медицинске радијационе физике и заштите од зрачења у медицини. Аутор је 199 научних и стручних радова, објављених у часописима и саопштених на скуповима међународног и националног значаја. Објавила је 53 радоа у међународним часописима а њени радови су до сада, не рачунајући аутоцитате, цитирани 356 пута. У више наврата усавршавала се у иностранству.

Др Оливера Цирај Бјелац, ванредни професор

Катедра за микроелектронику и техничку физику Електротехничког факултета у Београду

А. БИБЛИОГРАФИЈА НАУЧНИХ И СТРУЧНИХ РАДОВА

Оливера Цирај Бјелац је аутор 199 научних радова објављених у: еминентним међународним часописима са „*impact factorom*"-ом (укупно 53 у последњих пет година 27), еминентним међународним часописима (укупно 1, раније, пре више од пет година), домаћим часописима (укупно 10, раније, пре више од пет година), зборницима радова са међународних конференција (укупно 56, у последњих пет година 19) и зборницима са домаћих конференција (укупно 76, у последњих пет година 14).

А.1. Библиографија научних и стручних радова у последњих пет година

А.1. 1. Радови објављени у публикацијама категорије М10

M13. Monografska studija/poglavlje u knjizi ili rad u tematskom zborniku vodećeg međunarodnog značaja

1. Madan .M. Rehani and Olivera Ciraj-Bjelac. CT dose perspectives and initiatives of the IAEA, in Radiation Dose from Adult and Paediatric Multidetector Computed Tomography, 2nd ed, Editors D. Tack, M. Kalra, P.A. Gevenois, Springer, 2012, pages 495-509, http://books.google.rs/books?id=Sf2fwu_xkV8C&pg=PA495&lpg=PA495&dq=CT+dose+perspectives+and+initiatives+of+the+IAEA,+in+Radiation+Dose+from+Adult+and+Paediatric+Multidetector+Computed+Tomography&source=bl&ots=nUF3XM327n&sig=1AihWJepvNub069tPBbvx-2vcAg&hl=en&sa=X&ei=cMWcUvWdM8XnygOggYGQDw&ved=0CD8Q6AEwAQ#v=onepage&q=CT%20dose%20perspectives%20and%20initiatives%20of%20the%20IAEA%2C%20in%20Radiation%20Dose%20from%20Adult%20and%20Paediatric%20Multidetector%20Computed%20Tomography&f=false
2. Ciraj Bjelac O, Petrovic B, Todorovic N, Lucic S, Nikolov J, Veskovic M. Application of gamma radiation in medicine, in Gamma Rays: Technology, Applications and Health Implications, ed. Istvan Bikit, Nova Publishers, 2012, chapter 13, 321-344, https://www.novapublishers.com/catalog/product_info.php?products_id=36941

А.1. 2. Радови објављени у међународним часописима са SCI листе, категорија М20

М21а. Међународни часопис изузетних вредности

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М21. Радови објављени у врхунским међународним часописима

1. Olivera Ciraj-Bjelac, Eleftheria Carinou, Paolo Ferrari, Merce Gingaume, Marta Sans Merce, Una O'Connor , Occupational Exposure of the Eye Lens in Interventional Procedures: How to Assess and Manage Radiation Dose, Journal of Americal Colleauge of Radiology, 2016, 13(11), pp. 1347-1353, ISSN: 1546-1440, IF=2.929, DOI: 10.1016/j.ja cr.2016.06.015
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3. J. Farah, A. Trianni, O. Ciraj-Bjelac, I. Clairand, C. De Angelis, S. Delle Canne, L. Hadid, C. Huet, H. Jarvinen, , A. Negri, L. Novák, M. Pinto, T. Siiskonen, M. J. Waryn, and Ž. Knežević. Characterization

of XR-RV3 GafChromic® films in standard laboratory and in clinical conditions and means to evaluate uncertainties and reduce errors, Medical Physics 42, 4211-4226 (2015); ISSN: 0094-2405, doi: 10.1118/1.4922132, IF=3.012

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M22. Радови објављени у истакнутим међународним часописима

1. Hourdakis CJ, Büermann L, Ciraj-Bjelac O, Csete I, Delis H, Gomola I, Persson L, Novak L, Petkov I, Toroi P. Comparison of pencil-type ionization chamber calibration results and methods between dosimetry laboratories. Phys Med. 2016 Jan;32(1):42-51, ISSN: 1120-1797, doi: 10.1016/j.ejmp.2015.09.008, IF=2.403
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6. Farah JAD, Trianni Annalisa, Carinou E, Ciraj-Bjelac Olivera, Clairand Isabella, Dabin Jeremie, De Angelis Cincia, Domienik Joana, Jarvinen Hanu, Kopec Renata, Majer Maria Malchair Francoas, Negri Ana, Novák Leos, Siiskonen Timu, Vanhavere Filip, Kneževi? Zeljka. Measurement of maximum skin dose in interventional radiology and cardiology and challenges in the set-up of European alert thresholds. Radiat Prot Dosimetry. (2015) 164 (1-2): 138-142., doi: 10.1093/rpd/ncu314, ISSN: 0144-8420, IF=0.913
7. Ciraj-Bjelac Olivera, Gavrilovic Marijana, Arandjic Danijela, Vujovic Milan, Božovic Predrag. Radiation exposure during x-ray examinations in a large paediatric hospital in Serbia. Radiation Protection Dosimetry, 2015, 165(1-4):220-5. doi: 10.1093/rpd/ncv084., ISSN: 0144-8420, IF=0.913
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M31. Предавања по позиву са међународних скупова штампани у целини

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М 62. Предавање по позиву са скупа националног значаја штампано у изводу

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М 63. Саопштење са скупа националног значаја штампано у целини

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2. Predrag BOŽOVIĆ, Olivera CIRAJ-BJELAC, Danijela ARANĐIĆ, Katarina KARADŽIĆ, Jelena STANKOVIĆ i Sandra ĆEKLIĆ. PROCENA DOZE ZA OČNO SOČIVO KARDIOLOGA U INTERVENTIM PROCEDURAMA NA OSNOVU DOZE ZA CELO TELO, Zbornik radova 28. Simpozijuma Društva za zaštitu od zračenja Srbije i Crne Gore, Vršac, 30 Septembar - 2 Oktobar, 2015., pp: 307-309
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8. Antić V, Ciraj-Bjelac O, Arandić D, Stanković J, Todorović N, Lučić D. Doza od profesionalnih izlaganja u nuklearnoj medicini sa PET/CT praksom u Srbiji. Zbornik radova 27. Simpozijuma Društva za zaštitu od zračenja Srbije i Crne Gore, Vrnjačka Banja, 2-4 Oktobar, 2013., pp: 226-229

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А.2. 1. Радови категорије М10

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M21. Radovi objavljeni u vrhunskim medjunarodnim časopisima

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А.3. Цитираност радова

Цитираност радова Оливере Цирај Бјелац, без аутоцитата свих коаутора обухвата 356 цитата, h=10 (извор: SCOPUS.)

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Unit

- Medical Physics & Quality Assessment

Belongs to (according to the corporate view):

- Department of Imaging & Pathology

Functions

- associate professor (part-time) Faculty of Medicine
- head of Medical Physics & Quality Assessment
- member of Divisie Medische Beeldvorming
- member of the Division OMFS-IMPATH

Research topics of Bosmans Hilde

Quality assurnace in digital radiology and CT
Opitmalisation of digital mammography
Breast tomosynthesis
Patientdosimetry in radiology
Quality assurance of image processing software
MRI based Diffusion and Perfusion of extracranial tumors
Cone beam dental imaging

Bibliografija prof. dr Hilde Bosman

IT (Articles in internationally reviewed academic journals)

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Leuven, June 13, 2017

To whom it may concern,

Dear Madam, dear sir,

ONS KENMERK
UW KENMERK
HEVERLEE

With this letter, I would like to confirm that I approve the PhD manuscript of Sonja Ivanovic.

In the frame of her PhD project, she has done a substantial effort in increasing the quality in breast cancer screening in Montenegro.

I am obviously available for more information.

Kindest regards,

Prof. dr. ir. Hilde Bosmans

Biografija mr Sonje Ivanović

Sonja Ivanović je rodjena 17.07.1972.g. u Beogradu.
Osnovnu i srednju školu završila je u Podgorici kao odličan đak. Prirodno-matematički faultet, odsjek za fiziku, završava 1999.g.u Prištini, Univerzitet Republike Srbije.
Diplomu magistra medicinske fizike stiče 2009.g. na Multidisciplinarnim ACIMSI (Association of Centers for Interdisciplinary and Multidisciplinary Studies and Research) studijama na Univerzitetu Republike Srbije u Novom Sadu sa temom *"Definisanje fizičkih parametara snopa X-zračenja generisanog CT uređajem i osiguranje kvaliteta na klinici za dijagnostiku"*.

Doktorske studije započela je na Prirodno-matematičkom fakultetu u Podgorici, 2013.g. Ove doktorske studije dio su projekta Međunarodne Agencije za atomsku energiju (IAEA) iz Beča pod nazivom Coordinated Research Project (CRP) E24019 Doctoral CRP in "Advances in Medical Imaging Techniques", zahvaljujući kojoj je obezbijeđena mjerna oprema, vanjski mentor iz Belgije i studijski boravak na Institutu kod vanjskog mentora.

U Kliničkom centru CG, zaposlena je od 2000.g. prvo na odjeljenju za radioterapiju gdje je obavljala poslove medicinskog fizičara – planiranje zračne terapije i dozimetrijska kontrola Linearnog akceleratora. Od 2007, radi kao Načelnik odjeljenja za zaštitu na radu u Kliničkom centru i kao Lice odgovorno za zaštitu od zračenja. Decembra 2007. dobija nagradu za postignute rezultate u oblasti zaštite na radu od Vlade Crne Gore, Privredne komore, Unije sindikata i Udruženja za zaštitu na radu.

U toku svoga radnog staža, Sonja je obavljala funkcije vodje brojnih IAEA projekata u vezi dijagnostičke radiologije. Najvažniji do sada su bili *„Strengthening Radiological Protection of Patients and Medical Exposure Control"* gdje je radila na prikupljanju pacijentnih doza za procedure u Interventnoj radiologiji i CT-u i *„Upgrading the qualtiy Assurance and Quality Control Programme in Diagnostic Radiology for National Breast Screening Programme"* gdje je i dalje zadužena za sprovođenje programa osiguranja kvaliteta digitalnog mamografa. Rezultati iz oba ova projekta publikovani su u naučnim časopisima iz oblasti medicinske fizike u radiološkoj dijagnostici.
2008.g. Sonja je bila član radne grupe koja je napisala važeći Zakon o zaštiti od jonizujućeg zračenja.
2009. – član radne grupe koja je napisala Nacionalni akcioni plan u slučaju hemijskog, biološkog i radiološkog hazarda.
Takodje je bila član radne grupe za nuklearnu bezbjednost, poglavlje 15 – Energetika, u sklopu procesa integracije Crne Gore u Evropsku Uniju.
U toku **2015.** angažovana od IAEA za rad na Uspostavljanju QA/QC u radiološkoj dijagnostici razvijanjem vodiča i kriterijuma za regionalne centre za obuku u ovoj oblasti.
U toku 2016. – član grupe, po izbotu IAEA, koja je napisla Priručnik za osnovne testove kontrole kvaliteta za radiološku dijagnostiku - draft document u pripremi za publikovanje.
Od **2010.g.** je član RASIMS-a (Radiation Safety Information Management System) za Crnu Goru. Oblast za koju je zadužena je TSA3- Radiološka zaštita u medicinskom izlaganju.
Od **2016.** Sonja je Nacionalni fokal point za jonizujuće zračenje ispred Ministarstva zdravlja Crne Gore.

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