UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Slikanje z magnetno resonanco
Course title:	Magnetic Resonance Imaging

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Nanoznanosti in nanotehnologije, 3. stopnja	/	1	1
Nanosciences and Nanotechnologies, 3rd cycle	/	1	1

Vrsta predmeta / Course type Izbirni / Elective

Univerzitetna koda predmeta / University course code: NANO3-888

Predavanja Lectures	Seminar Seminar	Sem. vaje Tutorial	Lab. vaje Laboratory work	Druge oblike Others	Samost. delo Individ. work	ECTS
15	**15**			**15**	**105**	**5**

**Navedena porazdelitev ur velja, če je vpisanih vsaj 15 študentov. Drugače se obseg izvedbe kontaktnih ur sorazmerno zmanjša in prenese v samostojno delo. / This distribution of hours is valid if at least 15 students are enrolled. Otherwise the contact hours are linearly reduced and transfered to individual work.*

Nosilec predmeta / Lecturer: Prof. dr. Igor Serša

Jeziki / Languages:		
	Predavanja / Lectures:	slovenščina, angleščina / Slovenian, English
	Vaje / Tutorial:	

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Zaključena druga stopnja bolonjskega študija ali diploma univerzitetnega študijskega programa. Potrebna so tudi osnovna znanja fizike in matematike.	Completed Bologna second level study program or an equivalent pre-Bologna university study program. Basic knowledge of physics and mathematics is also requested.

Vsebina:	**Content (Syllabus outline):**
Osnove magnetne resonance: jedra v močnem magnetne polju, jedrska precesija, signal proste precesije, jedrska relaksacija, spinski odmev, jedrske interakcije, spekter signala jeder Slikanje z magnetno resonanco v eni dimenziji: gradient magnetnega polja, signal magnetne resonance v gradientu magnetnega polja, princip frekvenčnega kodiranja signala, slika magnetne resonance v eni dimenziji Razširitev v več dimenzij: rekonstrukcija slike in serije projekcij, fazno	Basics of magnetic resonance: nuclei in a strong magnetic field, nuclear precession, free precession signal, nuclear relaxation, spin echo, nuclear interactions, spectrum of a nuclear signal Magnetic resonance imaging in one dimension: magnetic field gradient, magnetic resonance signal in magnetic field gradient, principle of signal frequency encoding, magnetic resonance image in one dimension Expansion in two and more dimensions: image reconstruction from a series of

občutljiva detekcija signala, princip faznega kodiranja signala, uvedba k-prostora, rekonstrukcija slike na osnovi večdimenzionalne Fouriereve transformacije

Zaporedje za slikanje s spinskim odmevom:

vzbuditev signala v rezini, vpliv parametrov zaporedja na kontrast slike, relaksacijski časi bioloških tkiv, gostotna, T1 in T2 obtežena slika, slikanje v več rezinah ali z več odmevi

Zaporedje za slikanje z gradientnim odmevom

ravnovesno stanje longitudinalne magnetizacije, Ernstov kot, zaporedja FLASH, FISP in balanced-SSFP

Inverzija s povratkom

izločanje signala tkiv glede na njihov čas relaksacije T1, zaporedji STIR in FLAIR

Kontrastna sredstva

vpliv kontrastnih sredstev na skrajšanje relaksacijskih časov, uporaba za odkrivanje tumorjev

Magnetno resonančna angiografija

TOF angiografija, fazno kontrastna angiografija, angiografija s kontrastnimi sredstvi

Napredne metode slikanja

hitro slikanje z zaporedji RARE in EPI, difuzijsko slikanje, slikanje difuzijskega tenzorja, funkcijsko slikanje, kontrast na osnovi prenosa magnetizacije, vzporedno slikanje, hiperpolarizacija

Magnetno resonančna spektroskopija

metode lokalizacije signala, spektri različnih patologij

projections, phase-sensitive signal detection, principle of signal phase encoding, introduction of k-space, image reconstruction based on multi-dimensional Fourier transform

Spin-echo imaging sequence:

signal excitation in a slice, impact of imaging parameters on an image contrast, relaxation times of biological tissues, proton density-, T1- and T2- weighted image, imaging in several slices or with many spin echoes

Gradient-echo imaging sequence

steady state longitudinal magnetization, Ernst angle, FLASH, FISP and balanced-SSFP sequences

Inversion recovery

tissue signal elimination based on its T1 relaxation time, STIR and FLAIR sequences

Contrast agents

effect of contrast agents on relaxation time shortening, application for tumor detection

Magnetic resonance angiography

TOF angiography, phase contrast angiography, angiography with contrast agents

Advanced imaging methods

RARE and EPI fast imaging sequences, diffusion imaging, diffusion tensor imaging, functional imaging, magnetization transfer-based contrast, parallel imaging, hyperpolarization

Magnetic resonance spectroscopy

methods for signal localization, spectra of different pathologies

Temeljna literatura in viri / Readings:

Izbrana poglavja iz naslednjih knjig: / Selected chapters from the following books:

- SERŠA, Igor. Magnetnoresonančne preiskave. V: JEVTIČ, Vladimir (ur.), et al. *Diagnostična in intervencijska radiologija, Splošni del*. 1. izd. Maribor: Pivec, 2014, str. 88-106.
- Ray H Hashemi; William G Bradley; Christopher J Lisanti, *MRI : the basics*, Lippincott Williams & Wilkins, 2018, ISBN 978-1496384324.
- Catherine Westbrook, *MRI at a Glance*, Wiley-Blackwell, 2016, ISBN 978-1405192552.
- Alexander C. Mamourian, *MR Physics*, Oxford University Press, 2010, ISBN 978-0199706761.
- Marinus T. Vlaardingerbroek, Jacques A. Boer, *Magnetic Resonance Imaging: Theory and Practice*, Springer Science & Business Media, 2003, str.499. ISBN 3-540-43681-2.
- Matt A. Bernstein, Kevin F. King, and Xiaohong Joe Zhou, *Handbook of MRI Pulse Sequences*, Elsevier Academic Press, 2004, ISBN: 978-0-12-092861-3.
- Robert W. Brown,Y.-C. Norman Cheng,E. Mark Haacke, Michael R. Thompson, Ramesh Venkatesan, *Magnetic Resonance Imaging: Physical Principles and Sequence Design*, Wiley-Liss, 1999, ISBN 0-471-35128-8.

Cilji in kompetence:

Cilj predmeta je seznaniti študenta s področjem slikanja z magnetno resonanco. Pri predmetu bodo študentje spoznali osnove te napredne metode slikanja in se na osnovi številnih primerov tudi seznanili z njeno uporabo v medicinski diagnostiki. V predmet bodo vključene tudi praktične vaje, ki se bodo izvajale v Laboratoriju za slikanje z magnetno resonanco na IJS.

Kompetence študenta z uspešno zaključenim predmetom bodo vključevale razumevanje osnovnih principov slikanja z magnetno resonanco in poznavanje področij uporabe te metode v medicini.

Objectives and competences:

The aim of the course is to acquaint students with the field of magnetic resonance imaging. In it, the students will learn the basics of this advanced imaging method and based on a number of cases also become familiar with its use in medical diagnostics. The course will also include practical exercises that will be carried out in the Laboratory for magnetic resonance imaging at JSI.

The competencies of the students successfully completing this course will include understanding of the basic principles of MRI as well as basic knowledge of its use in medicine.

Predvideni študijski rezultati:

Študenti bodo z uspešno opravljenimi obveznostmi tega predmeta pridobili:

- znanje o osnovah magnetno resonančnega slikanja (fizikalni principi ter matematični algoritmi rekonstrukcije slik)
- pridobili pregled nad različnimi metodami MR slikanja in njihovimi posebnostmi
- spoznali bodo področja uporabe magnetno resonančnega slikanja v medicinski diagnostiki
- na primerih praktičnih vaj se bodo neposredno srečali z opremo, potrebno za magnetno resonanco slikanje in tudi v praksi spoznali, kako nastane slika z magnetno resonanco
- seznanili se bodo tudi z nevarnostmi pri tej metodi, tako z vidika pacienta kot tudi operaterja
- na osnovi pridobljenega znanja bodo zmožni samostojno spremljati in razumevati strokovno literaturo s področja slikanja z magnetno resonanco in se udeleževati mednarodnih srečanj s tega področja

Intended learning outcomes:

Students successfully completing this course will acquire:

- knowledge about the basics of magnetic resonance imaging (physical principles and mathematical algorithms of image reconstruction)
- got an overview of different MRI methods and their specificities
- learn about the scope of MRI in medical diagnostics
- with practical classes they will get familiar with MRI hardware and they will learn how MR image is acquired
- students will learn a potential danger with the method from perspective of the patient as well as the operator
- with the gained knowledge they will be able to follow and understand the scientific literature in the field of magnetic resonance imaging and to attend international meetings on MRI

Metode poučevanja in učenja:

Predavanja, parktične vaje, konzultacije, individualno delo.

Študentje bodo praktične vaje opravili v Laboratoriju za slikanje z magnetno resonanco na IJS.

Learning and teaching methods:

Lectures, practical classes, consultancy, individual work.

Students will have practical classes on MRI in the Laboratory for magnetic resonance imaging at JSI.

Načini ocenjevanja:	Delež (v %) / Weight (in %)	Assessment:
Seminarska naloga	50 %	Seminar work
Ustni zagovor seminarske naloge	50 %	Oral defense of seminar work

Reference nosilca / Lecturer's references:

- BAJD, Franci, ŠKRLEP, Martin, ČANDEK-POTOKAR, Marjeta, VIDMAR, Jernej, SERŠA, Igor. Use of multiparametric magnetic resonance microscopy for discrimination among different processing protocols and anatomical positions of Slovenian dry-cured hams. Food chemistry, 2016, vol. 197, part B, str. 1093-1101.
- VIDMAR, Jernej, KRALJ, Eduard, BAJD, Franci, SERŠA, Igor. Multiparametric MRI in characterizing venous thrombi and pulmonary thromboemboli acquired from patients with pulmonary embolism. Journal of magnetic resonance imaging, 2015, vol. 42, issue 2, str. 354-361.
- SERŠA, Igor, BAJD, Franci, MOHORIČ, Aleš. Effects of off-resonance spins on the performance of the modulated gradient spin echo sequence. Journal of magnetic resonance, 2016, vol. 270, str. 77-86.
- KODER, Gregor, SERŠA, Igor. Magnetic resonance Imaging of mechanical deformations. Magnetic resonance imaging, 2016, vol. 34, iss. 2, str. 137-143.
- BAJD, Franci, MATTEA, Carlos, STAPF, Siegfried, SERŠA, Igor. Diffusion tensor MR microscopy of tissues with low diffusional anisotropy. Radiology and oncology, 2016, vol. 50, no. 2, str. 175-187.