GENERAL INFORMATION		
Course name	**Nuclear Medicine**	
Course director	**Prof. Ivica Mihaljević, MD, PhD**	
Assistants		
Study program	**Integrated undergraduate and graduate university study program Medical Studies in German**	
Course status	Mandatory	
Year of study, semester	4th year, 8th semester	
Credits allocated and form of instruction	ECTS student workload	**3**
	Number of teaching hours (L+S+E)	**40** (15+10+15)

COURSE DESCRIPTION

Course objectives

Familiarization with diagnostic and therapeutic procedures in nuclear medicine and indications for their rational application. Familiarization with the specificities of working with open sources of radiation, the concept of radiopharmaceuticals, basic safety standards and principles of protection against ionizing radiation. After the class, students should be able to rationally and expertly understand the indications for the most common diagnostic and therapeutic procedures in nuclear medicine, while respecting the principle of justification, optimization and dose limits. Familiarization with hybrid imaging technologies, principles of protection of occupationally exposed persons and the public. Knowledge of the most common thyroid diseases, rational diagnosis and choice of therapeutic approach.

Course requirements

There are no specific requirements for this course except those defined in the study program curriculum.

Learning outcomes relevant to the study program

1.2, 2.1, 2.2, 2.3, 3.1, 3.2, 3.3, 3.4, 3.5, 4.1, 4.2

Expected learning outcomes *(5-10 learning outcomes)*

Knowledge

1. Radiopharmaceuticals and radionuclides – definition, list and describe the most important diagnostic and therapeutic radionuclides and their physical characteristics (radiated energy and physical half-life). Concept of ideal radiopharmaceutical, biodistribution mechanisms. Describe the production of radiopharmaceuticals, the generator principle.
2. Describe the instrumentation in nuclear medicine and the principles of creating a planar image on a gamma camera, as well as the basics of reconstruction in SPECT and PET tomography.
3. Describe and recognize the additional contribution of hybrid technologies (SPECT/CT and PET/CT).
4. List the most commonly used nuclear medicine diagnostic imaging (i.e. “in vivo”) methods and radiopharmaceuticals, according to organ systems.
5. Define and describe the role of nuclear medicine in the diagnosis of emergency situations.
6. Therapeutic procedures in nuclear medicine – distinguish between diagnostic and therapeutic use of radiopharmaceuticals, summarize the physical, chemical and biological bases for the use of radionuclides in disease treatment, list examples of therapeutic radionuclides.
7. Diagnostics and treatment of thyroid diseases – list the physical properties of iodine-123,131, and the differences from other iodine isotopes (iodine 123, iodine 125, iodine 124), discuss the purpose of measuring radioiodine accumulation and

scintigrams in benign diseases that can be treated with radioiodine; explain how radioiodine is used in the treatment algorithm for patients with thyroid cancer.

8. Describe the principles of working with open sources of radiation and protection when working with them, and recognize the fact that the patient is the source of radiation in nuclear medicine. Concept, ways of contamination.

Skills

1. Demonstrate the skill of safe work with open sources of radiation and protection when working with them. Proper application of protective equipment and protective measures when exposed to ionizing radiation. Prevention of contamination, procedures after discharge of patients with therapeutically applied radionuclide.
2. Adequately inform and prepare the patient for the diagnostic procedure with open radionuclides, especially women of childbearing age, distinguish absolute contraindications. Recognize specially protected groups of patients in radiation protection. Adopt the principle of optimization, justification and limitation.
3. Interpret the most common deviations in T4/FT4, T3/FT3, TSH, TPOAb, TRAb findings. Understand the concept of reference range, the physiology of feedback loops. Recognize clinical pictures of hyperthyroidism and hypothyroidism. A rational approach to the diagnosis of thyroid disease. Approach to the nodule and goiter.
4. Basics of treatment with thyrostatic drugs and LT4. Most common side effects and procedure.
5. Understand the findings on ultrasound of thyroid gland, neck organs and cytological analysis.
6. Application of the most important radiopharmaceuticals and diagnostic procedures according to organ systems, following leading indications.
7. Basic understanding of PET/CT findings, especially 18F-FDG. Patient preparation, knowledge of the indication list in oncological application. Understand and explain the importance of hybrid diagnostics.

Course content

Radioactive tracers in biology and medicine: relationship between morphology and function. Nuclear medicine and its specificities. Radioactivity, nuclides. Isotopes in medicine. Nuclear medicine as an in vivo application of radioactive tracers. Application of open radionuclides in in vivo and in vitro diagnostics and in treatment. Production of radiolabeled compounds (radiopharmaceuticals). Measuring radioactivity, counters. Behavior of radioactive substances in the body. Simultaneous examination of the morphology and function of organs and organ systems. Molecular nuclear medicine: labeling of complex compounds, receptors, specific monoclonal antibodies, metabolites and drugs. *Scintigraphy: devices, gamma camera, SPECT, scintigram processing using computer and PET/CT.* Physical basis of nuclear medicine. Main types of radioactive decay. Interaction of α, β and γ radiation with matter. Detection of radioactivity and detector efficiency. Structure of a gamma scintillation counter. Pulse analyzer, counting system and visualization. Diagnostic devices: gamma camera, SPECT (single-photon emission computed tomography) camera and PET/CT (positron emission tomography/computed tomography). *Radiopharmaceuticals: production and preparations of radionuclides (radiopharmaceuticals). Biodistribution mechanisms.* Definition, classification and selection of radiopharmaceuticals. Properties of an ideal radiopharmaceutical and radionuclide. Quality control of radiopharmaceuticals. Routes of administration of radiopharmaceuticals, distribution mechanisms, half-lives. Radionuclide generators. Physical properties of the most commonly used isotopes in nuclear medicine. ^{99m}Tc and radiopharmaceuticals labeled with them. Diagnostic radiopharmaceuticals. Radiopharmaceuticals in nephrourology: (MAG3, DTPA, ECD, DMSA), cardiology (^{201}Tl, SESTAMIBI and tetrofosmin), hepatology (IDA derivatives and colloids), pulmonology (MAA, Technegas, aerosols and noble gases), neurology (HMPAO, ECD and ioflupane), osteology (bisphosphonates), inflammatory diseases (^{67}Ga, monoclonal antibodies and leukocyte markers). ^{131}I, ^{123}I. Therapeutic radionuclides and radioimmunotherapy. *Diagnostics and treatment of thyroid diseases: measuring radioiodine accumulation, scintigraphy, ultrasound,*

cytology. Thyroid diseases. Autoimmune diseases. Endocrine orbitopathy. Goiter and nodules. Thyroid cancers. Pathology, epidemiology and clinic. Congenital diseases. Hypothyroidism, hyperthyroidism, classification and the most common etiological causes. Diagnostics of thyroid disease. Radionuclide tests, in vitro tests. USG, cytological analysis. *Immunoanalysis in determining concentrations of thyroid hormones, antibodies and tumor markers.* Concept and principles of radioimmunoassay. Classification of RIA methods. Competitive and non-competitive RIA with derivatives and comparison with competitive methods. Thyroid hormones: biosynthesis, serum transport, distribution and hypothalamic-pituitary axis. Free and total T4 and T3. Thyroid autoantibodies (TPOAb, TRAb, TgAb): epidemiology, functional, clinical and pathological significance, role in diagnostics and prognosis of thyroid disease. Tumor markers in thyrology: thyroglobulin, calcitonin and their role in patient monitoring. *Treatment of thyroid disease*. Pharmacological and radical treatment of Graves' disease. Hormone replacement therapy. Surgical treatment of thyroid disease and Mb Basedow radioiodine therapy, treatment of toxic adenoma and toxic nodular goiter. Methods of calculating the therapeutic activity of ^{131}I in benign thyroid diseases. Application techniques, standard operating procedures in radionuclide therapy and hospital discharge conditions. Guidelines for the choice of treatment. Diffuse and nodular non-toxic goiters and endemic goiter. Salt iodization. Diagnostic algorithms for the evaluation of nodular goiters and indications for radical treatment and PH verification. Principles of surgical treatment of thyroid disease and extent of resection. Diagnostics and treatment of subacute thyroiditis. Principles of care, diagnostic process and surgical treatment of suppurative thyroiditis. *Nuclear medicine in cardiology, myocardial perfusion scintigraphy.* Functional aspects of diagnostics in cardiology: perfusion, metabolism, viability and kinetics of myocardium. Radiopharmaceuticals in perfusion studies (^{201}Tl, ^{99m}Tc agents: SESTAMIBI, tetrofosmin). Mechanisms of accumulation and distribution of perfusion agents. Myocardial perfusion and metabolism in ischemic heart disease, the concept of reversible and irreversible defects. Indications for myocardial perfusion scintigraphy, performance and imaging techniques, pharmacological and physical stress. SPECT and gated-SPECT. Importance of perfusion scintigraphy in the diagnostics of ischemic heart disease, prognosis and risk stratification before and after revascularization. Investigations of myocardial metabolism (^{18}F-FDG PET). Viability and hibernation. Shunt detection and quantification. Types of shunts. *Nuclear medicine in oncology.* PET/CT and PET/MR. Molecular imaging. Metabolism (FDG, amino acids), proliferation, hypoxia, antigens and receptors (somatostatin). Advantages of functional imaging. Fusion of function and morphology. ^{18}F-FDG. Indications: differentiation between benign and malignant, NM staging, effect of therapy (restaging) and prognosis, viability and recurrence, CUP. Sites, refunded indications. Overview of representative indications. New radiopharmaceuticals: ^{68}GaDOTA* (NET), ^{18}F-choline (prostate), ^{11}C-Met. Neuroendocrine tumors, SSTR (^{68}Ga-DOTATOC, ^{99m}Tc-Tektrotyd), $^{123/131}$I-MIBG. *Nuclear medicine in gastroenterology*. Nuclear medicine diagnostics of infections/inflammation. Scintigraphic imaging in gastroenterology. Esophageal scintigraphy, motility: radiopharmaceuticals, clinical indications, preparation, imaging procedure, visual analysis and quantification. Curves of the passage of activity through the esophagus. Scintigraphy of gastroesophageal reflux. Liver and spleen RES scintigraphy with ^{99m}Tc-(S) colloid: clinical indications. Splenic scintigraphy (denatured E): clinical indications. Hepatobiliary scintigraphy (^{99m}Tc-IDA): preparation, radiopharmaceuticals, clinical indications, imaging procedure. Presentation of normal elimination of ^{99m}Tc-HIDA from liver parenchyma and pathological findings. Scintigraphy of gastrointestinal bleeding: the most common sites of bleeding from the GI tract, localization of bleeding. Pathological findings criteria, radiopharmaceuticals, imaging procedure and normal findings. Characteristics of radiopharmaceuticals: ^{99m}Tc-(S) colloid and ^{99m}Tc-erythrocytes. Scintigraphy of Meckel's diverticulum: clinical indications, radiopharmaceutical, preparation and imaging procedure and description of findings. Scintigraphy of liver hemangioma with ^{99m}Tc-erythrocytes. Absorption studies: Schilling test. *Nuclear medicine in nephrology and urology.* Partial renal functions: perfusion, plasma flow, GF and clearances. Radiopharmaceuticals in nephrourology. Pharmacokinetics and dynamics of tubular (MAG3, OIH), glomerular (DTPA) agents and cortical tubular mass agent (DMSA). Key principles of

renography: performance, type and analysis of renograms. Static, dynamic and diuretic renal scintigraphy and clinical indications. Diagnostics of renovascular hypertension. *Nuclear medicine in neurology.* Radionuclide examinations of the brain, SPECT and PET/MR. Indications: cerebrovascular diseases, neuro-oncology, basal ganglia diseases, epileptogenic foci, cognitive dysfunction and dementia. Flow and perfusion reserve (HMPAO, ECD, ^{15}O-H2O, ^{133}Xe), metabolism (FDG, amino acids-Met, FET), receptor and transmitter studies. Parkinson's disease, components. Radiopharmacy of dopamine neurotransmission. ^{123}I-FP-CIT/IBZM, ^{18}F-DOPA. Differential diagnosis. *Radiation protection: basics of dosimetry, biological effects of ionizing radiation and medical procedures in case of excessive radiation.* Exposure to radiation. Dosimetry and the ALARA principle. Protective equipment and protective measures. Radiation doses and dosimetric units: absorbed, equivalent and effective dose. The effect of an equivalent dose of radiation on humans. Events in the body after irradiation. The parts of the cell most sensitive to ionizing radiation. Tissue sensitivity to ionizing radiation. Genetic mutations and chromosomal aberrations. Factors affecting biological damage caused by ionizing radiation. Classification of radiation effects. Effects of excessive radiation on the body. Protection. Procedures in case of excessive radiation or contamination. *Nuclear medicine in examining the skeletal system: scintigraphy of bones and joints and bone marrow.* Osteotropic radiopharmaceuticals, diphosphonates. Biodistribution mechanism. Procedures for performing planar, three-stage and SPECT studies. A normal finding. Osteoblastic and osteolytic lesions. Clinical indications: primary bone cancers (benign and malignant), metastatic bone cancers, rheumatic diseases, aseptic necrosis, osteomyelitis (^{99m}Tc-HMPAO, ^{111}In-leukocytes, ^{99m}Tc-MAK), fractures (stress fractures, viability), metabolic diseases of the skeleton, prosthetics joints, trauma. ^{18}FDG-PET/CT in inflammation and bone cancers.

Form of instruction	☒lectures ☒seminars and workshops ☒exercises ☐distance learning ☐field course	☐individual assignments ☐multimedia and Internet ☐laboratory ☐mentoring activities ☐other

Student obligations

Come to class prepared by studying the recommended literature for each unit and actively participate in all forms of instruction. The student must participate in at least 70% of classes to pass the course.

Monitoring student learning

Attendance	x	Active participation	x	Seminar paper		Experimental work	
Written exam	x	Oral exam	x	Essay		Research	
Project		Continuous assessment		Paper		Practical work	
Portfolio							

Assessment and evaluation of students during class and on the final exam

Students' performance will be evaluated during class and on the final exam. Students are evaluated numerically and descriptively (insufficient (1), sufficient (2), good (3), very good (4), excellent (5)). During classes, a student can earn a maximum of 100 points. Students can earn a maximum of 20 points during classes through different types of activities. On the final exam, students can earn a maximum of 80 points. The final grade represents the sum of the points earned during classes and on the final exam.

Mandatory reading

1. Schicha H, Schober O. Nuklearmedizin: Basiswissen und klinische Anwendung. Schattauer; Auflage: 6. 2007

Additional reading

1. Büll U, Schicha H, Biersack HJ, Knapp WH, Reiners C, Schober O. Nuklearmedizin. Thieme; Auflage: 4, 2007

2. Dietlein M, Kopka K, Schmidt M. Nuklearmedizin: Basiswissen und klinische Anwendung. Schattauer; Auflage: 8, 2017
3. Grünwald F, Derwahl KM. Diagnostik und Therapie von Schilddrüsenkrankheiten: Ein Leitfaden für Klinik und Praxis. Lehmanns; Auflage: 2, 2016
4. http://www.snm.org (Society of Nuclear Medicine)
5. http://www.eanm.org (European Association of Nuclear Medicine)
6. http://www.nuklearmedizin.de (DGN, Deutsche Gesellschaft für Nuklearmedizin)

The number of copies of mandatory reading in proportion to the number of students currently taking this course

Title	*Number of copies*	*Number of students*
Schicha H, Schober O. Nuklearmedizin: Basiswissen und klinische Anwendung. Schattauer; Auflage: 6. 2007	*20*	*60*

Quality monitoring methods ensuring the acquisition of knowledge upon completion, skills and competences

The quality of course performance is monitored through an anonymous student survey on the quality of the organization and conduction of classes, the course content and the work of professors. The usefulness of the lectures from the students' perspective, the curriculum content, the professor preparedness, the clarity of the presentation, the amount of new content and the quality of the presentation are evaluated. The curriculum and its execution are administratively compared. The participation of students in lectures and exercises, as well as the excuses for missing classes, are controlled and analyzed.