



Ultrasound Diagnostics in Infectious Disease

SSI Curriculum 26.10.2023

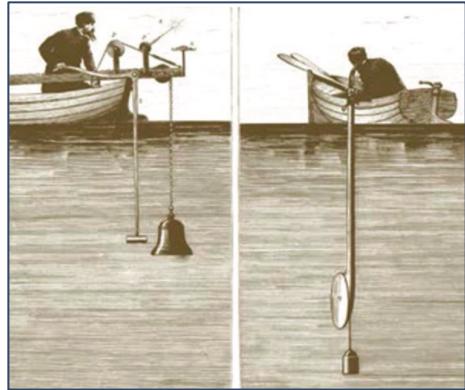
Dr. med. Sebastian Haubitz, LA Infektiologie & Allg. Innere Medizin, Kantonsspital Aarau

Overview

- History of diagnostic ultrasound (a story of recent success)
- Thorax: lungs and pleura (readily available & easy to learn)
- Liver and biliary system (diagnostic standard)
- Kidneys and urinary tract system (complications)
- Intestines / abdominal cavity (diagnostic standard)
- Lymph nodes and spleen (growing importance with high resolution imaging)
- Take home messages – what comes next?

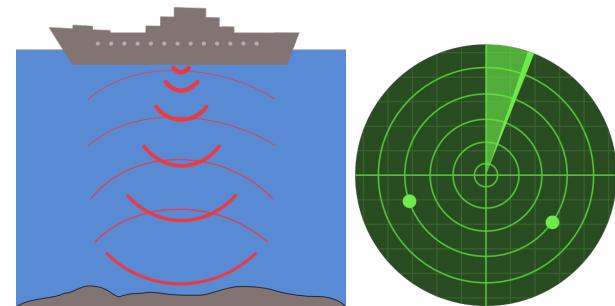
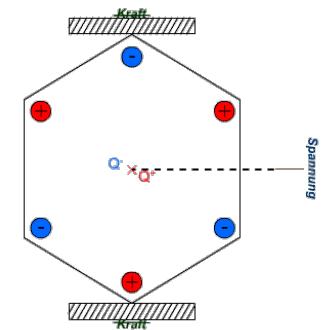
History of ultrasound imaging 1

- Lazzaro Spallanzani (1729 - 99), Italian scientist – and bishop: Bats need their ears for navigation...
- Jean-Daniel Colladon (1802 - 93), Swiss physicist, Jacques Charles-Francois Sturm (1803–1855): Sound travels faster in water than through air
- Christian Doppler (1803 - 53), Austrian physicist: „On the coloured light of binary stars“



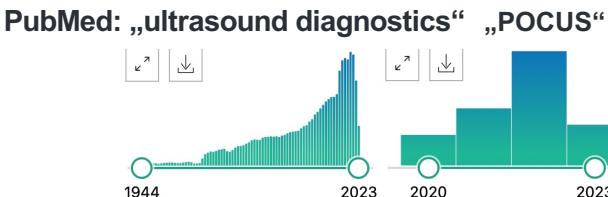
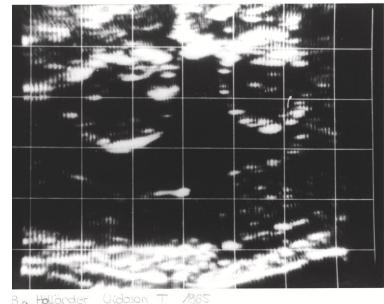
History of ultrasound imaging 2

- Jacques (1856 - 1941) & Pierre (1859 - 1906) Curie: Piezoelectricity
- Titanic 1912 → Alexander Behm, deutscher Physiker: Sonar (Behmlot → Echolot)
- Karl Theo (1908 - 68) & Friedrich (1910 - 88) Dussik: 1942 Hyperphonography (cerebral ventricle measurement)
- World War II: Sonar and Radar



History of ultrasound imaging 3

- 1940er Experiments on sonography in medicine (cardiology, abdominal surgery, gynecology, ophthalmology)
- 1967 real time B-scan: „Vidoson“ (W. Krause & R. Soldner; Siemens Medical Systems, Erlangen)
- 1980/90er Jahre: birth of modern ultrasound diagnostics: Colour-coded doppler, tissue harmonic imaging, elastometry, contrast enhanced, 4D, etc.
- 1980 foundation of SGUM(B) → 2000 FA Sonographie
2018 POCUS



Thorax: Lungs & pleura

- Pleural effusion and empyema
 - Better sensitivity of ultrasound imaging ($> 5 \text{ ml}$) than Rx ($> 150 \text{ ml}$) for detection of pleural effusion
 - Planning standard for pleural puncture / thoracentesis
 - Highly specific but mediocre sensitive for complicated pleural effusion & empyema → **no rule out!**
 - Diagnostic criteria: hyperechogenic / inhomogenous effusion, and Septation
 - CT-diagnostic performance similar, not better

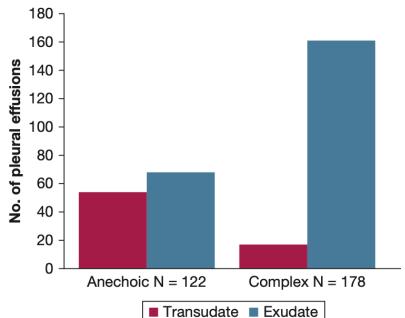
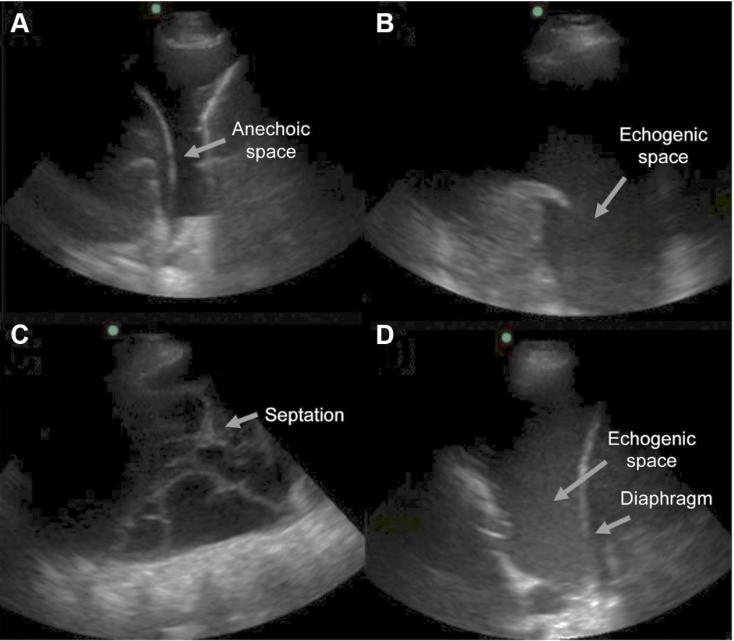


TABLE 4] Diagnostic Performance of Thoracic Ultrasonography Findings for Pleural Diagnosis

Variable	Sensitivity	Specificity	Pleural diagnosis
Simple anechoic that resulted in transudative effusion	76 (64-85)	70 (64-76)	Transudative
Complex echogenic effusion that resulted in exudative pleural effusion	70 (64-76)	76 (64-85)	Exudative
Complex septated and complex homogenous effusion that resulted in exudative pleural effusion	44 (37-50)	94 (86-98)	Infectious Malignant Other

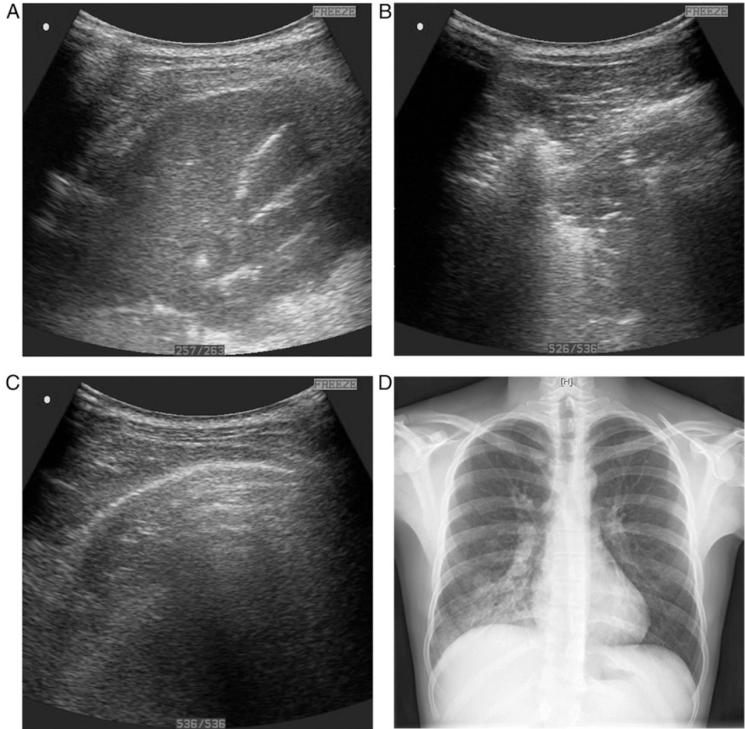


Thorax: Lungs & pleura

- Importance of puncture and diagnostic workup of pleural effusion if cause is not apparent (bilateral effusion in heart failure), especially unilateral. Or if size is clinically relevant.
- **Exsudate:** Light's-criteria when either one of...
 - Protein in effusion / serum > 0.5
 - LDH effusion / serum > 0.6
 - LDH > 2/3 UNL (>170 U/L)
- **Empyema:**
 - Septations in ultrasound image!
 - Exsudate, neutrophils count!, pH < 7.2

Thorax: Lungs & pleura

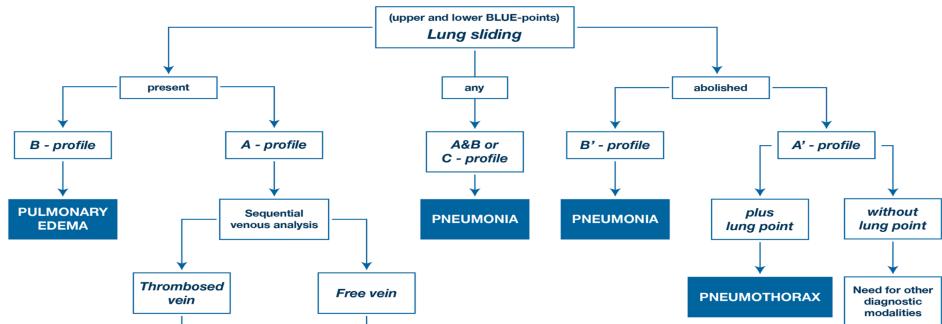
- LUS (TUS): Pneumonic infiltrates
 - High sensitivity (94%) and specificity (96%) in adults (even better in children with pneumonia)
 - **Ultrasound criteria / features:**
 - localised consolidations, breath-dependent
 - often with bronchoaerogram
 - (pulsatile) lung pulse (vs. atelectasis)
 - +/- pleural effusion (uncompl. / complicated?)
 - Only if infiltrate reaches pleural ($\geq 8\%$ missed infiltrates)



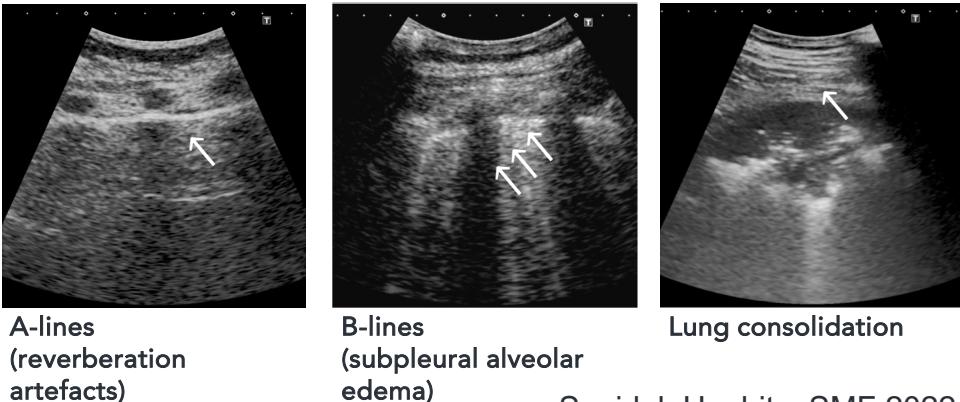
Reissig. CHEST 2012
Chavez. Respir. Research 2014
BTS Guidelines 2015
Wilcox. JAMA 2014
Light. Proc Am Thorac Soc 2006

Thorax: Lungs & pleura

- LUS (TUS): interstitial syndrome
 - Causes: pulmonary edema, interstitial pneumonitis, ARDS
 - Ultrasound criteria:
 - interpretation of mostly artefacts!
 - B-profile (≥ 3 B-lines(↖)/ICS) in ≥ 2 zones/hemithorax
 - +/- (uncompl.) pleural effusion
 - POCUS guided decision algorithm in acute respiratory distress



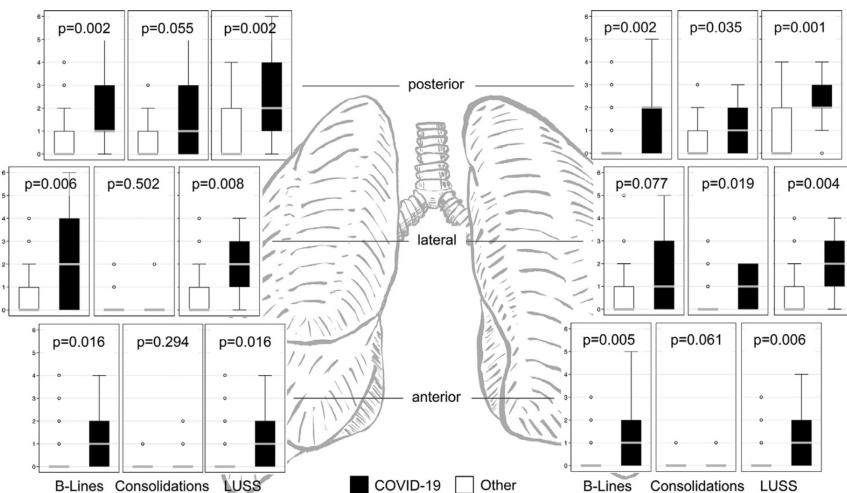
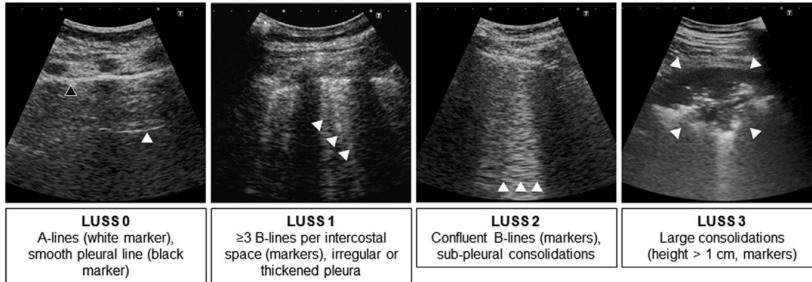
„Blue Protocol“. Mayo.
Intensive Care Med 2019



Speidel, Haubitz, SMF 2022

LUS in Covid-19

- Interstitial syndrome +/- consolidations
- Cohort: 11 Covid-19 + 38 other (PCR neg) (KSA 2020)
38 COVID-19 negative:
 - 10 (26%) extrapulmonary infection/inflammation
 - 8 (21%) pneumonia of other etiology
 - 7 (18%) exacerbated asthma or COPD
 - 4 (11%) pulmonary neoplasia
 - 2 (5%) pulmonary embolism
 - 2 (5%) congestive heart failure
 - 5 (14%) other
- LUSS ≥ 8 points: Sens 91% (59 - 100%)
Spec 76% (60 - 89%)



Speidel, Haubitz, Ultrasound Med. Biol. 2021

Liver and bile ducts

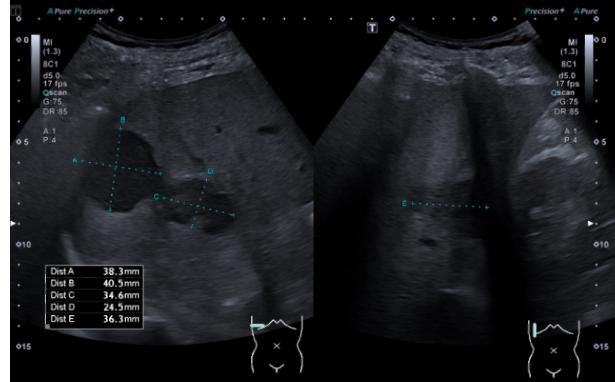
- **Acute cholecystitis**
 - **Cause:** usually obstruktive = ascending infection bei cholezystolithiasis / -docholithiasis
 - **Ultrasound criteria:** sonographic Murphy's sign (PPV 90%), wall thickening >3 mm + 3-layered wall edema (+Murphy's: PPV 99%), stones!, fluid layer, hydrops
 - **Treatment:** early cholecystectomy (à chaud / „golden 72 hours“); thereafter conservative plus elective cholecystectomy (à froid)
 - amoxicillin/clavulanic acid or ceftriaxone +/- gentamicin
 - **+ biliary obstruction?** (DHC > 7 mm; intrahepatic „double-barrel“ sign) → ERCP first!
 - **Differential diagnosis of wall thickening:** CHF/right heart decompensation; portal hypertension / ascites, acute hepatitis, adenomyomatosis, cholangiocarcinoma (segmental)
 - **Acalculous cholecystitis** (rare in critically ill patients / in shock (ICU), TPN, immune deficiency)



Liver and bile ducts

- Liver abscess

- Cause:** 60% ascending infection via bile ducts; hematogenous: 10% via V. portae, 10% via A. hepatica
- Ultrasound criteria:** initially mostly hypoechoic, gas?, fuzzy borders, hypoechoic halo (edema)
→ encapsulation and liquefaction, often multiple
- Amoebic liver abscess:** initially frayed margins; later often very large (5 – 20 cm) with smooth capsule (up to 1 cm)
- Diagnostic puncture/drainage:**
if unclear or when large & symptomatic (rupture risk)
Pigtail drainage feasible when size > approx. 2.5 cm
- Treatment:** targeted antibiotics after pathogen detection > 4-6 weeks;
if empirical amoxicillin/clavulanic acid or ceftriaxone + metronidazole



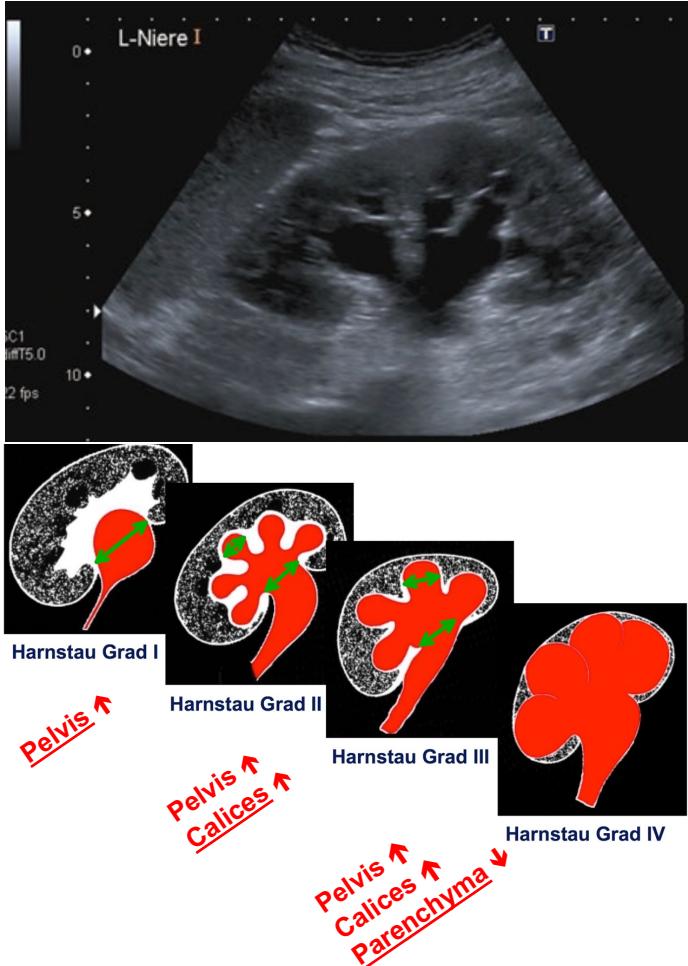
Liver and bile ducts

- Hepatitis: fibrosis → cirrhosis
 - **Causes:** viral (acute HAV, HEV, HBV u.a. CMV, EBV...; chron. HBV +/- HDV, HCV), autoimmune, toxic (alcohol), metabolic (NAFLD)
 - **Ultrasound criteria:**
 - Acute hepatitis: mostly unremarkable! hilar lymph nodes, splenomegaly, little ascites and thickened gallbladder wall
 - Chronic: steatosis → fibrosis → cirrhosis (Metavir 4):
 - hyperechogenous parenchyma → attenuated image / diminished image in dorsal areas
 - increased stiffness in transient liver elastography (e.g. Fibroscan®)
 - complications: cirrhosis, portal hypertension, ascites, carcinogenesis (HCC)
 - **Treatment** according to etiology: HBV, (HDV), HCV, autoimmune, NAFLD...



Kidneys and urinary tract

- Acute pyelonephritis
 - **Cause:** ascending urinary tract infection (UTI) (enterobacteriaceae, mostly E. coli; enterococci; S. aureus associated with catheters and foreign material)
 - **Ultrasound criteria:** Pain on pressure, otherwise mostly unremarkable! In severe case thickened urothelium >2mm and enlarged kidney
 - Exclude obstruction: urolithiasis, tumor, pregnancy, etc.
- Renal abscess:
 - **Ultrasound criteria:** hypoechoic area in cortex, initially fuzzy demarkation → later thickened wall, sometimes gas.



Michels, Jaspers. Springer 2012

Kidney and urinary tract

- Acute prostatitis
 - **Ultrasound criteria:**
 - acute: mostly unremarkable! Hypoechoic, enlarged prostate gland →
 - chronisch: calcifications
 - **Complication: Prostate abscess:**
 - anechoic lesion

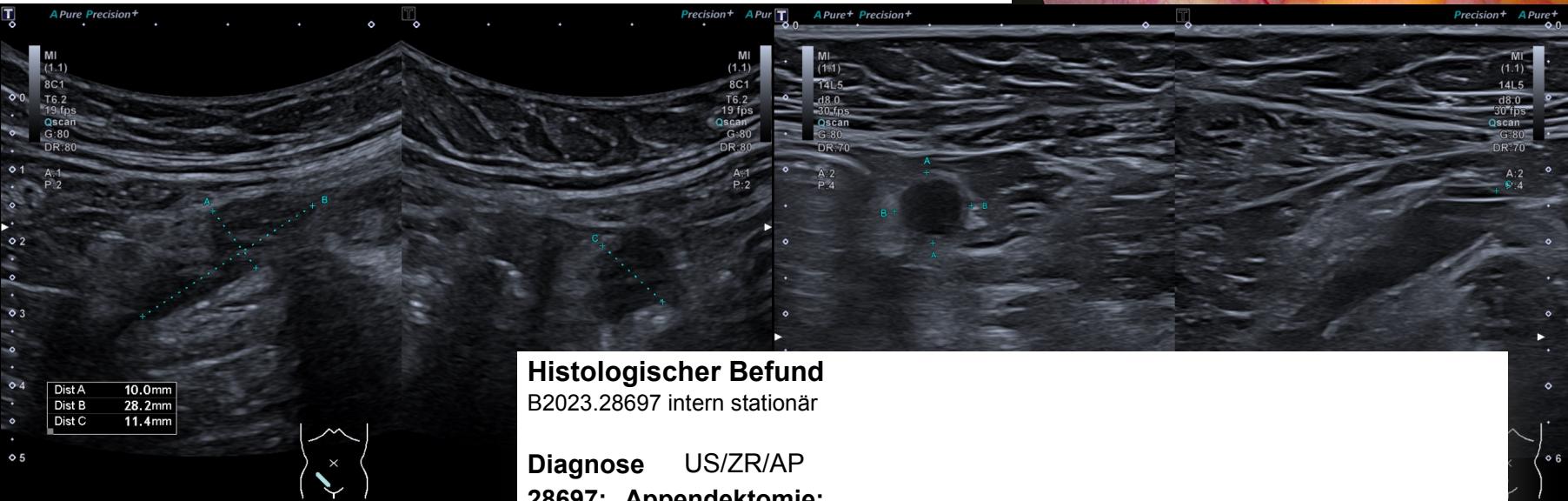
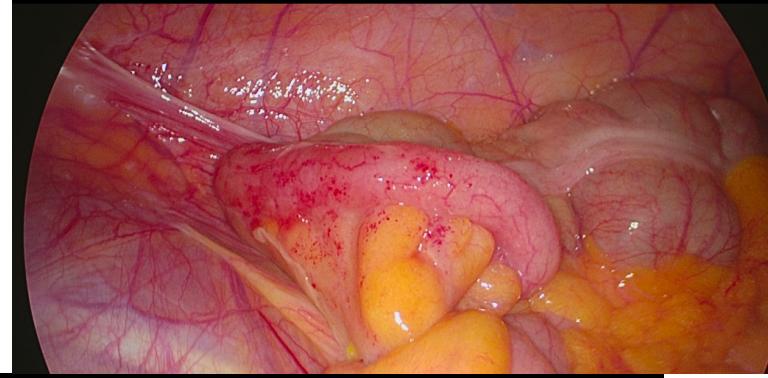


Intestines / abdominal cavity

- Appendicitis acuta
 - **Cause:** obstruction of appendix by fecal stones etc.
 - **Clinical features:** Pain over Lanz/McBurney, Blumberg-, Rovsing-sign → peritonism
 - **Ultrasound criteria:**
diameter > 6 mm, lack of compressibility, initially wall layering retained →
 - ulcerophlegmonös: hypoechogetic / fuzzy, fluid pathways, hypervascularisation
 - Sensitivity depends on anatomy examiners experience (according to literature: 80%)
→ CT or TVUS?

Intestines / abdominal cavity

Acute appendicitis



Histologischer Befund

B2023.28697 intern stationär

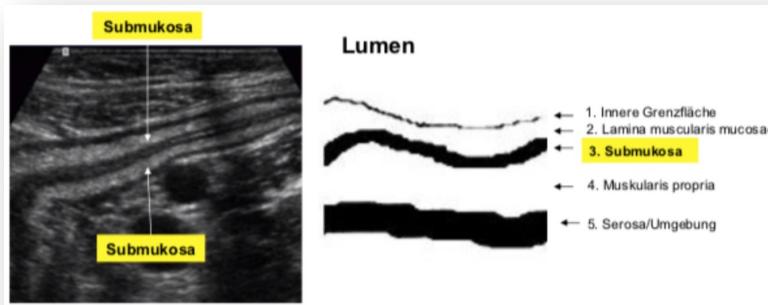
Diagnose US/ZR/AP

28697: Appendektomie:

Akute ulzero-phlegmonöse Appendizitis mit fibrinös-eitriger Peritonitis.
Kein Dysplasie- oder Malignitätsnachweis.

Intestines / abdominal cavity

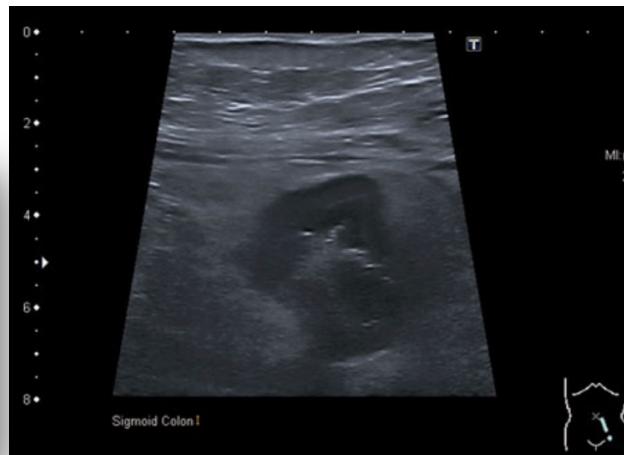
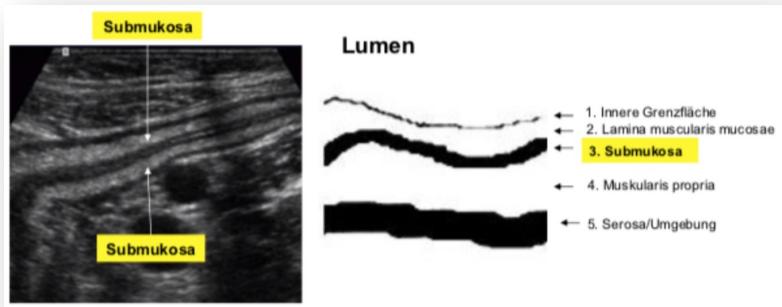
- enteritis / colitis
 - **Varied causes:**
 - ambulatory in CH mostly viral or toxic; sometimes immunologic
 - Immunosuppressed patients: CMV, kryptosporidium, neutropenic colitis
 - nosocomial setting: C.diff., ischemic
 - **Ultrasound criteria:** variable, hypermotile fluid-filled small bowels, colon wall thickening
→ schwere Kolitis: periluminale Flüssigkeit, Wandschichtung aufgehoben (pseudotumorös), pneumatosis coli (intramural air)



- Ø small intestine < 25 mm; colon < 50 mm
- wall thickness small intestines << 2 mm; colon < 2-3 mm
- characteristics colon: haustra, gas; small intestines: fluid-filled

Intestines / abdominal cavity

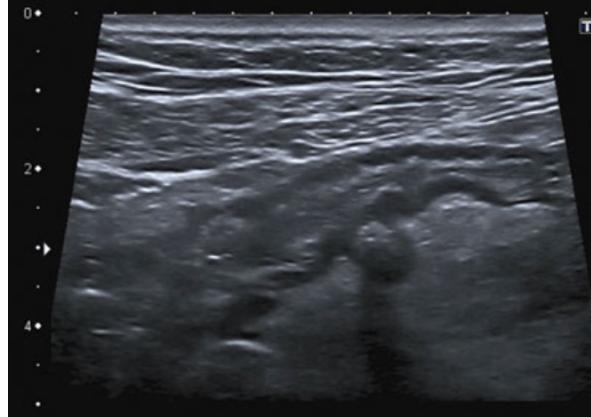
- Ischemic enteritis / colitis
 - NOMI vs. OMI: acute artery occlusion 85% AMS (small intest. + prox. colon)
>> Tr. coeliacus (stomach, pancreas, liver, gall bladder)
 - **Ultrasound criteria:** dilated, fluid-filled intestines, absence of peristalsis, markedly hypoechoogenic and thickened bowel wall, ascites



Michels, Jaspers. Springer 2012

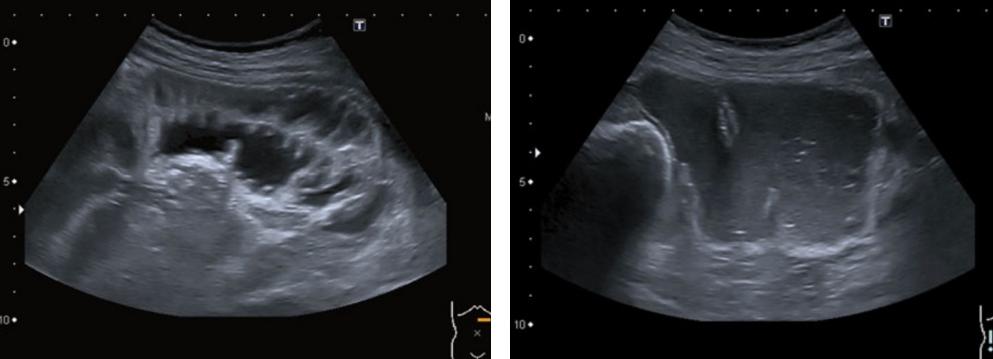
Intestines / abdominal cavity

- Diverticulitis
 - usually sigma is affected (95%)
 - Clinical feature: „left sided appendicitis“
 - **Ultrasound criteria:** localised pain (usually very precise) + presence of diverticula → hypoechogetic halo, fluid pathways → sometimes abscess or perforation
 - Sensitivity depends on anatomy examiners experience (literature: 97% - CT)
 - **Complications:**
 - Abszess (hypoechogetic, gas!)
 - perforation (gas ventral of liver in 30°- 45° left lateral position)



Intestines / abd. cavity

- Ileus
 - Mechanical (obstructive) vs. paralytic (reactive)
 - **Ultrasound criteria:**
 - Fluid-filled dilated (round) bowels, often ascites
 - small intestines: „piano keys“- / „rope-ladder“-phenomenon (Kerckring folds)
 - colon: massive hyperinflation auf haustras
 - mechanical: pendulum peristalsis, prestenotic dilatation / collapsed poststenotic bowel „Hungerdarm“
 - Paralytic: lack of peristalsis (also later in mechanical ileus!)

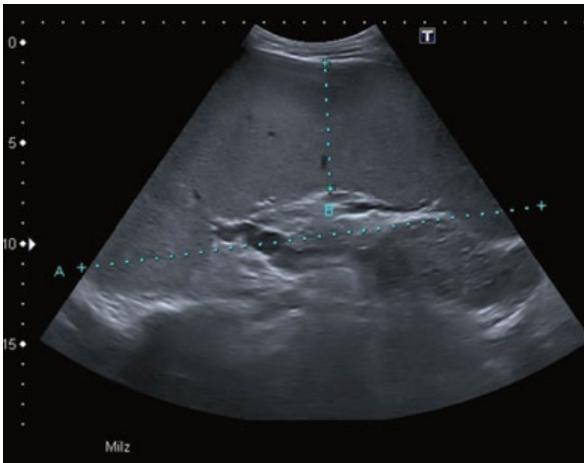


Intestines / abdominal cavity

- Ascites
 - **Varied causes:** portal hypertension, heart failure/decompensation, anasarca, malignant, infectious
 - **Ultrasound criteria:** anechoic compressible areas of fluid
 - Morrison's, Koller's pouch, excavatio rectovesicalis and Douglas' space
 - Paracentesis:
 - Diagnostic workup: Cell count & differential; culture (1 pair BC, if peritonitis suspected)
 - > 250 neutrophils/mm³ → Peritonitis (e.g. SBP)
 - SAAG (Albumin_{serum} – Albumin_{ascites}):
 - < 11 g/l → „peritoneal barrier disorder“: peritoneal carcinosis, peritonitis, pancreatitis, mesenteric infarction, poly-serositis, mechanical ileus
 - > 11 g/l → portal hypertension / > 25 g/l right heart failure

Lymphatic organs (LN, spleen)

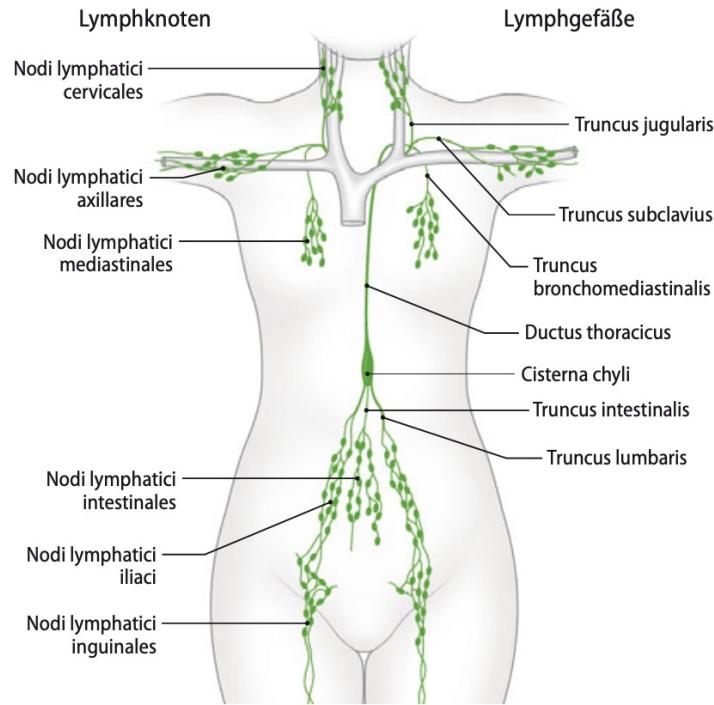
- Splenomegaly
 - Causes: infectious (mostly viral!), infiltrated, portal hypertension
 - **Ultrasound criteria:** „4711“: normal ≤ 11 cm / s'megaly ≥ 14 cm
→ better: volume normal < 200-300 ml (body size and sex, i.e. use Splenocalc®)



Michels, Jaspers. Springer 2012

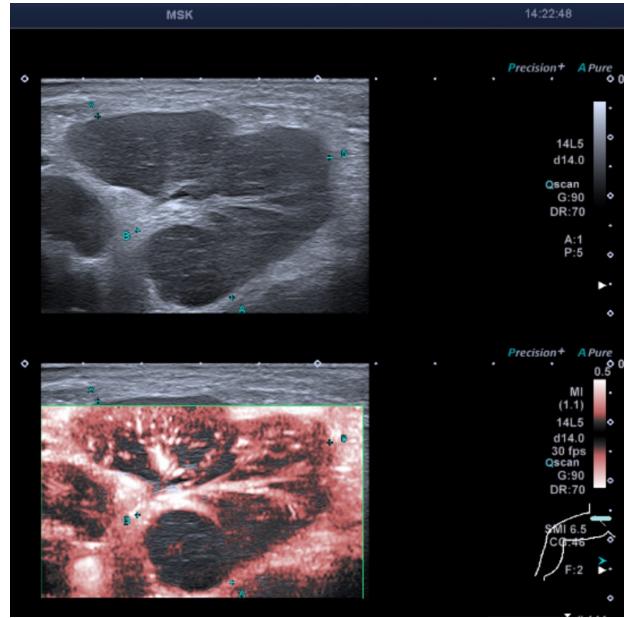
Lymphatic organs

- **Lymphadenopathy**
 - **Causes:** reactive, infiltrated, malignant (lokalised, general)
 - Normal ultrasound picture: 2 zones: defined central hilus and hypoechoogenic cortex
 - B-scan + duplex suitable for categorization and differential diagnosis of enlarged LN
 - **1) size:** max. short axis diameter!
 - cervical \leq 5 mm
 - thoracic \leq 10-15 mm
 - retroperitoneal \leq 10 mm
 - iliac \leq 12 mm



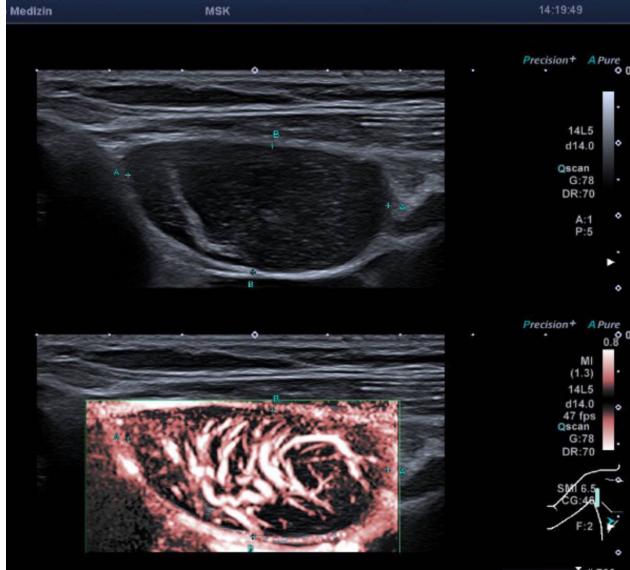
Lymphatic organs

- Lymphadenopathy
 - 2) shape:
 - Zeppelin-shaped vs. roundish
 - longitudinal-/transverse axis ratio (Solbiati-Index):
 - $>2 \rightarrow$ mostly benign
 - $<1,5-2 \rightarrow$ possibly malignant
 - clear borders vs. fuzzy/blurred
 - 3) border:
 - regular: mostly benign
 - irregular/growing into environment \rightarrow often malignant
 - 4) tenderness = rapidly growing \rightarrow rather reactive
 - enlarged but not tender \rightarrow possibly malignant



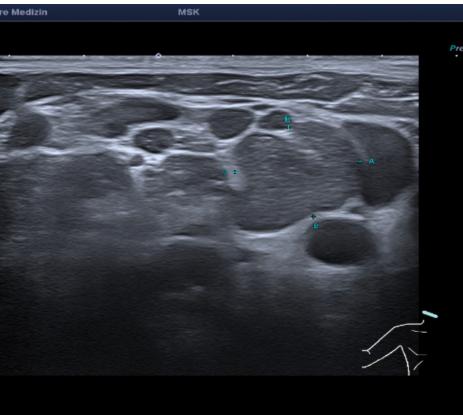
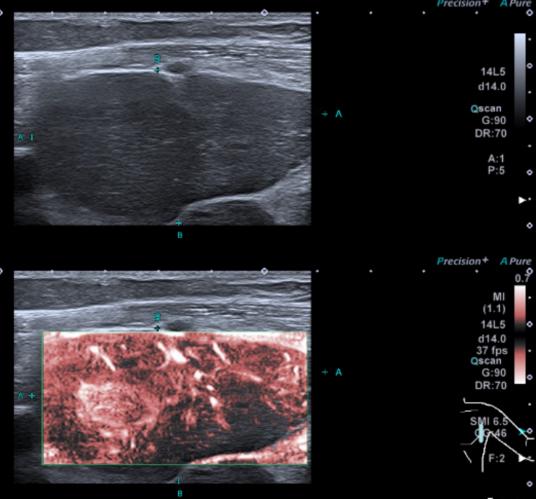
Lymphatic organs

- Lymphadenopathy
 - 5) echo structure/homogeneity:
 - Hilus : total lymph node ratio: $\geq 1/3 \rightarrow$ benign
 - homogeneous / inhomogeneous
 - hypoechogetic areas: necrosis
 - Hyperechogenic dots: e.g. in CLL
 - prominent central band: benign! (fatty degeneration)
 - Highly malignant lymphomas often markedly hypoechogetic
 - Tbc: »cloudy« structure



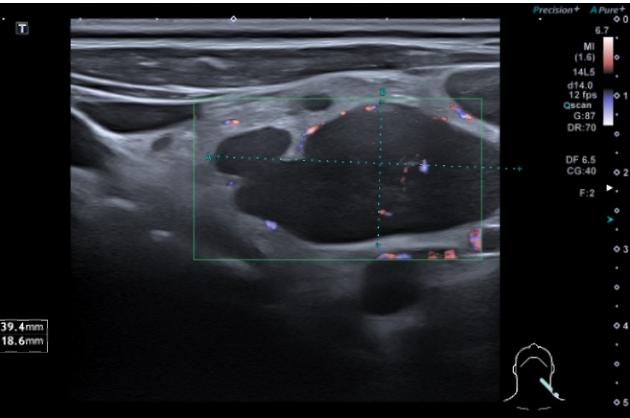
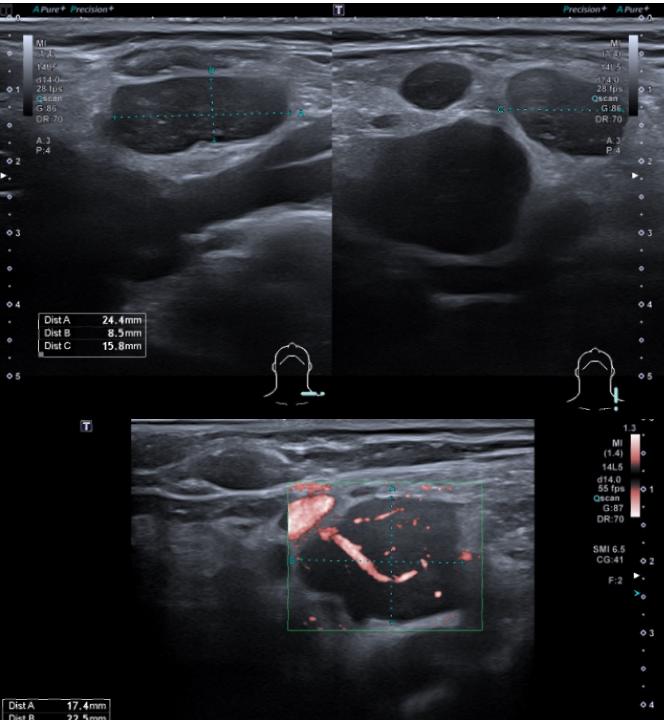
Lymphatic organs

- Lymphadenopathy
 - 6) vascularization:
 - singular hilar vessel → benign
 - branched central vessel: reaktiv (DD lymphoma!)
 - peripheral vessels → metastasis?
 - non-vascular → necrosis (infectious/malignant)
 - 7) localised vs. generalized:
 - localised: reactive or malignant
→ if unclear: watch and wait 4 weeks before biopsy!
 - generalized: infectious vs. lymphoma
→ differential blood count, EBV, CMV, HIV, Toxo etc.
→ if unclear: biopsy! (or FNP)



Lymphatic organs

Granulomatous lymphadenitis DD sarcoidosis



Molekularpathologischer Befund
H2023.1289 intern ambulant

Diagnose RG/ksamamrc

1289: Lymphknoten supraklavikular links (Exzisat):
Granulomatöse Lymphadenitis.

Untersuchung auf Mykobakterium tuberculosis DNA mittels PCR: Negativ.
Untersuchung auf Mykobakterium spezies DNA mittels PCR: Negativ.

RESEARCH

Open Access

Application of neck ultrasound
in the diagnosis of sarcoidosis



Take home!

Advantages with ultrasound imaging (vs. Rx / CT / MRT)

- Readily available / dynamic / includes clinical presentation → immediate decision-making tool
- Cost-effective; hardly any side effects or contraindications → repeatable (surveillance!)
- Guidance for puncture → monitoring of puncture complications
- Limitations: obesity, meteorism, examiner experience

Diagnostic tool for clinicians → POCUS

- Diagnostic standard for liver & biliary tract, urinary tract, sometimes even intestinal disease
- LUS > Rx in respiratory distress/failure, pleural effusion, pneumonia
- Additional information in work up of lymphadenopathy

What's next?

- Growing possibilities / areas of application: in lung/thorax, lymph nodes, in soft-tissue/osteo-articular diseases, POCUS with immediate decision algorithms
- POCUS basic/emergency (module 1) as part of FMH board certification general internal medicine (rev. 01/2022)
- Increasing importance and often integral component of infectious diseases diagnostic workup → important to learn and teach!