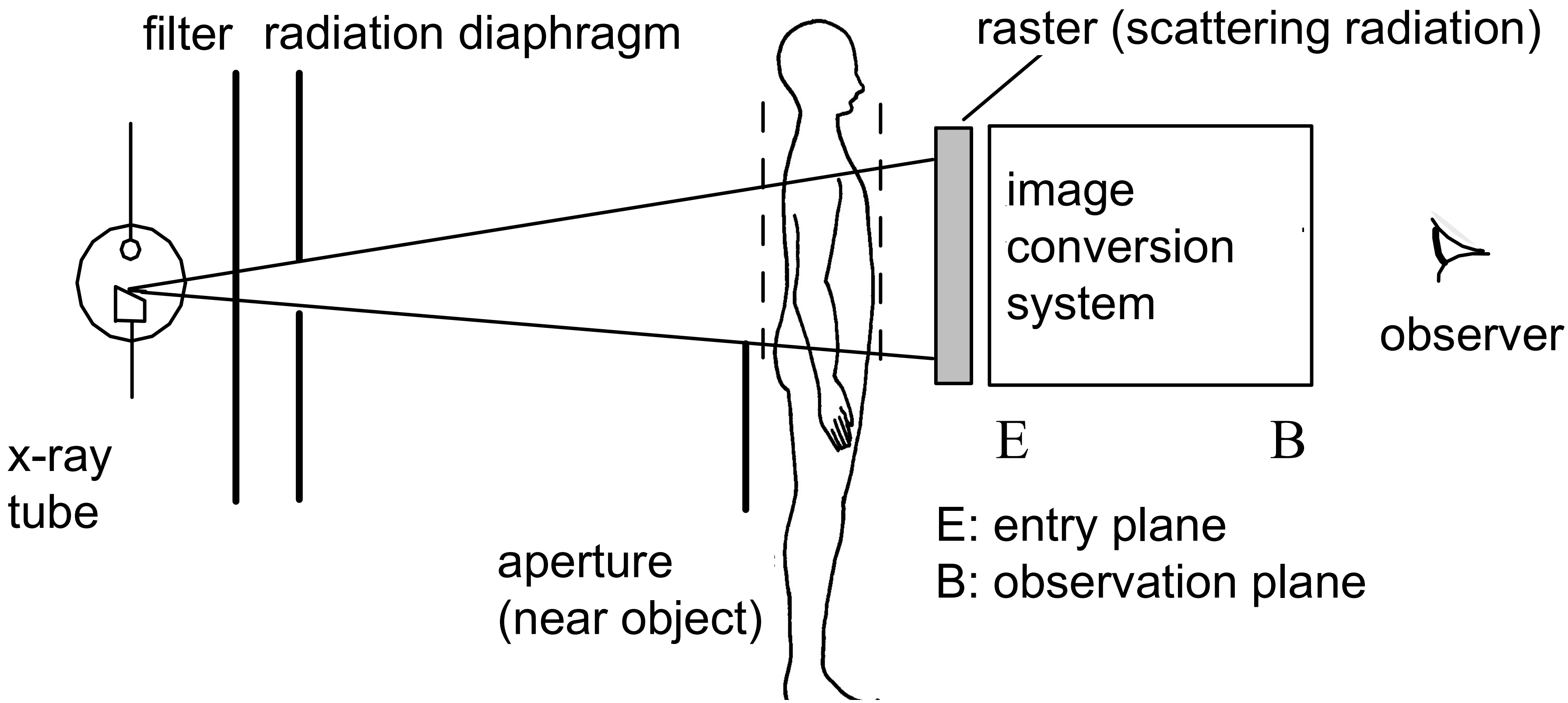
projection-radiography

principle: *fluoroscopy*

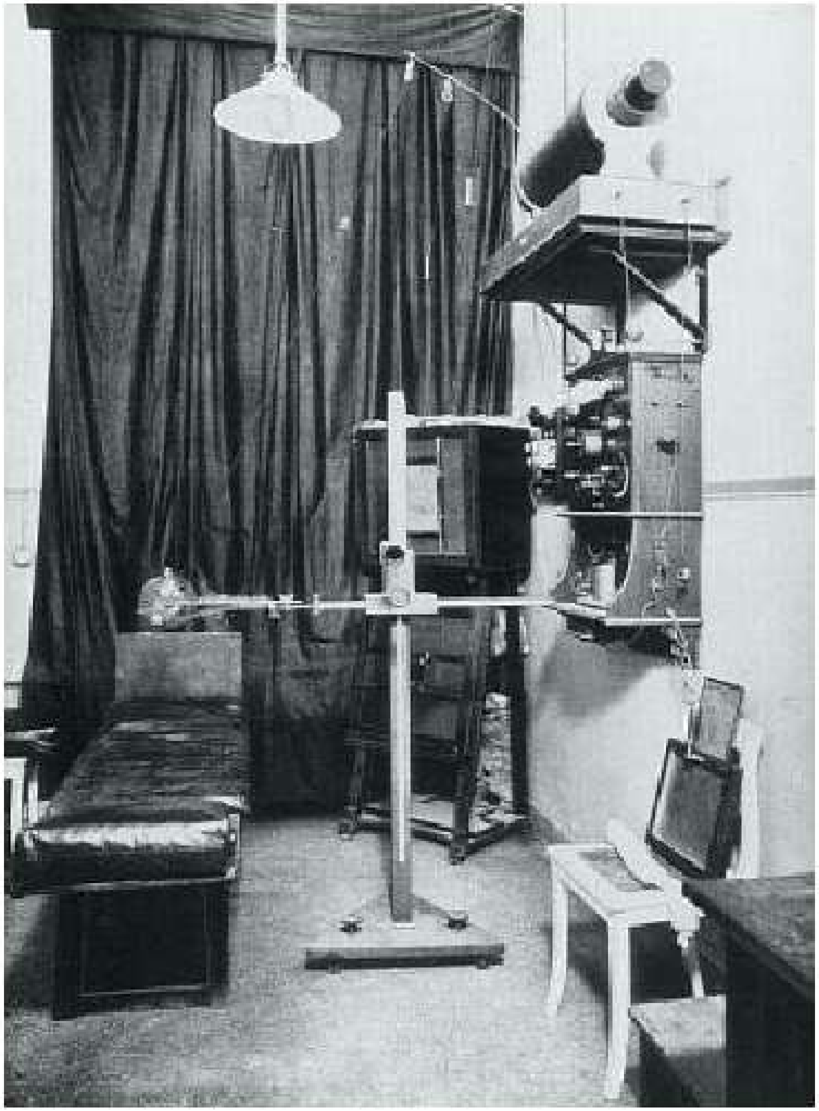


projection-radiography

An x-ray examination room (Mayo Clinic, Rochester, Minnesota, circa 1925) with <u>bare high-voltage cables</u> (arrow-heads) and little shielding of the x-ray tube (arrow)

source: Gray JE, Orton CG, Radiology 2000, 217:619-625

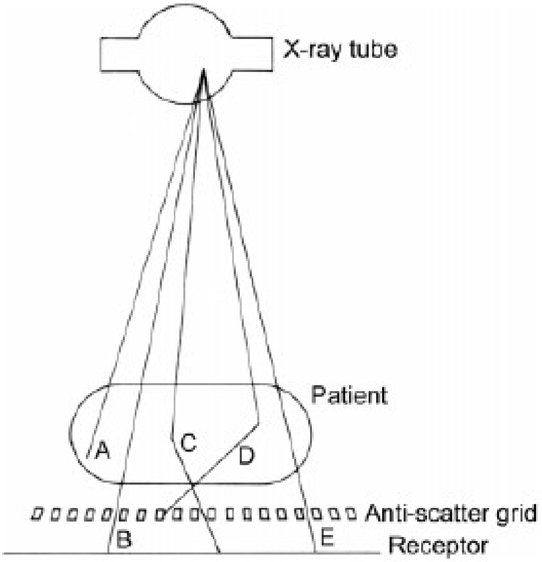
projection-radiography



x-ray investigation room (around 1900)

x-ray investigation room (around 2000)

projection x-ray system for film / amplifier foils



source: Siemens Medical

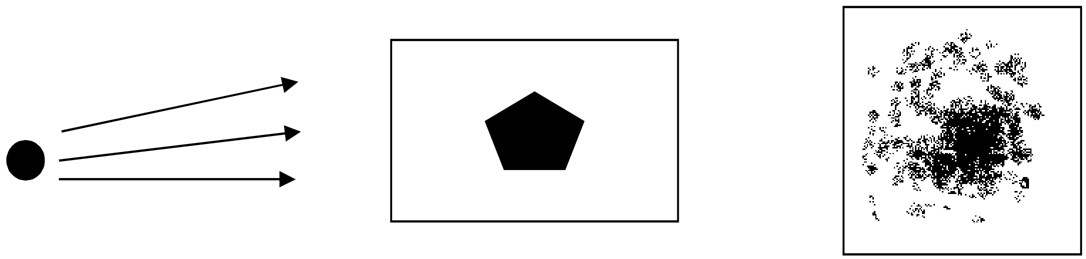
x-ray image amplifier system

source: Siemens Medical

projection-radiography

principle of measurement

x-ray source patient detector



J_0 $\mu(x,y,z)$ J_D

$\mu = f(e^{-}\text{-density}, Z^3)$

$$J_D = J_0 e^{-\int \mu(x,y,z)\,dl}$$

line integral of attenuation

attenuation: absorption (photo effect) and scattering (inelastic)

radiographic image:

- distribution of γ-quanta transmitted through tissue
- 2D-projection of attenuation properties of tissue

attenuation

lin. attenuation coeff. = mass attenuation coeff. · density

$$\mu = \mu_m \cdot \rho$$

tissue	Z_{eff}	density (g/cm^3)
bones	11.6	1.75
fat	6.3	0.92
muscle	7.4	1.00

image contrast: different Z_{eff} for bones and soft tissue

but: no clear-cut distinction between different soft tissues

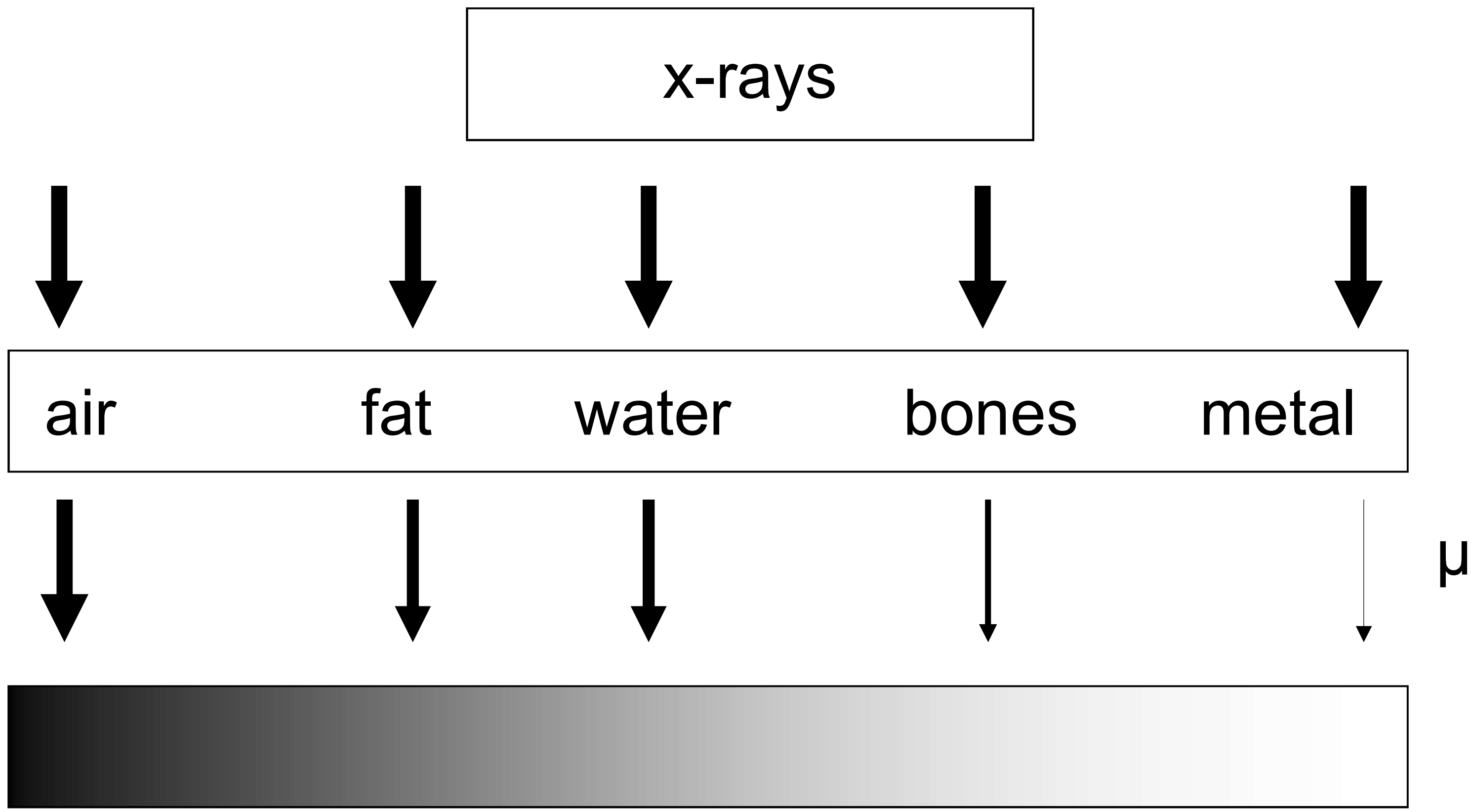
attenuation coefficients of biologic tissues @60 keV

tissue	attenuation coefficient (cm^{-1})
blood	0.215
brain tissue	0.210
water	0.203
fat	0.185
bones	0.400
air	0.0002

blood, brain tissue, water: hard to distinguish

water/fat, fat/bones: easy to distinguish

attenuation coefficient and film blackening

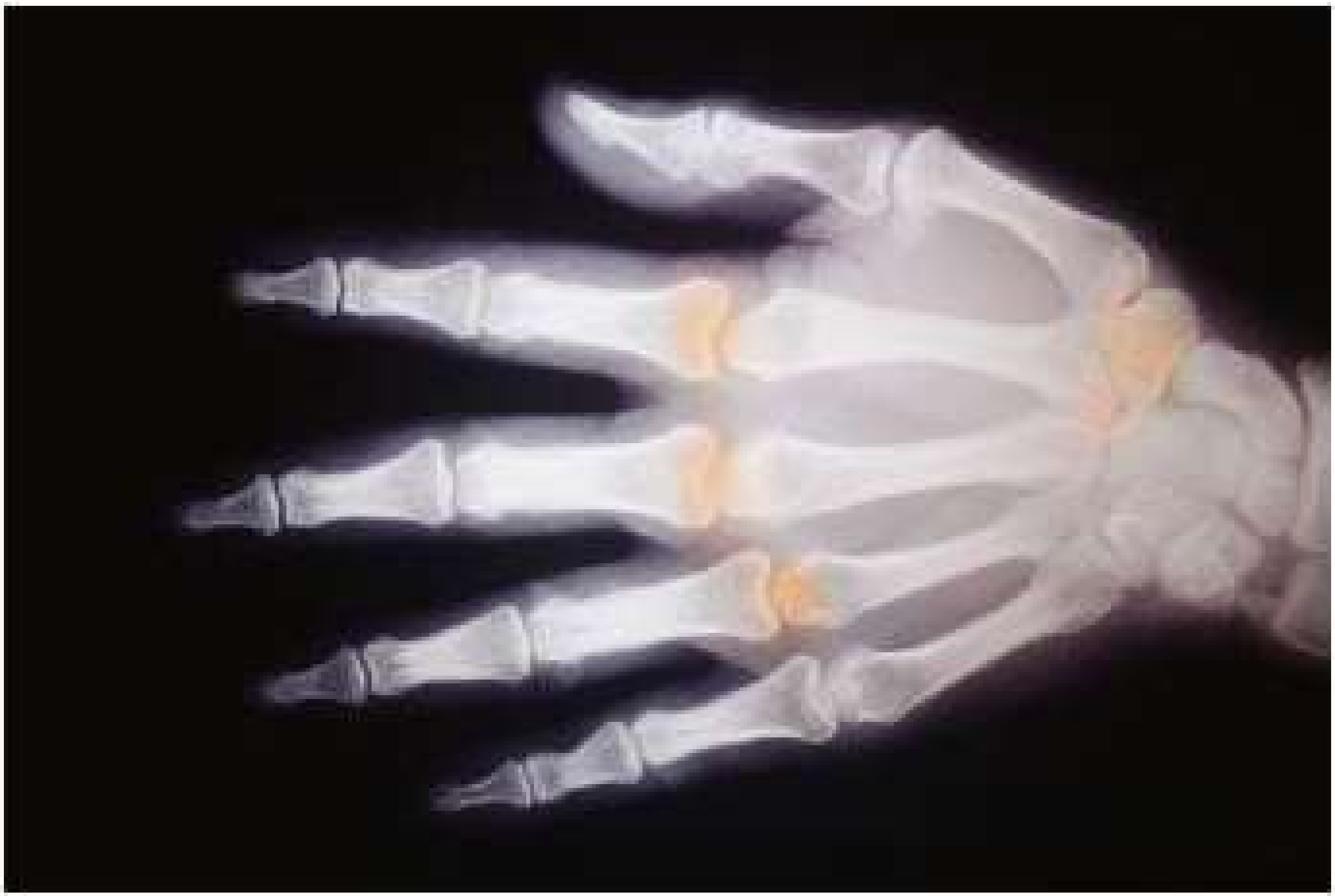


projection-radiography

chest radiograph

hand radiograph

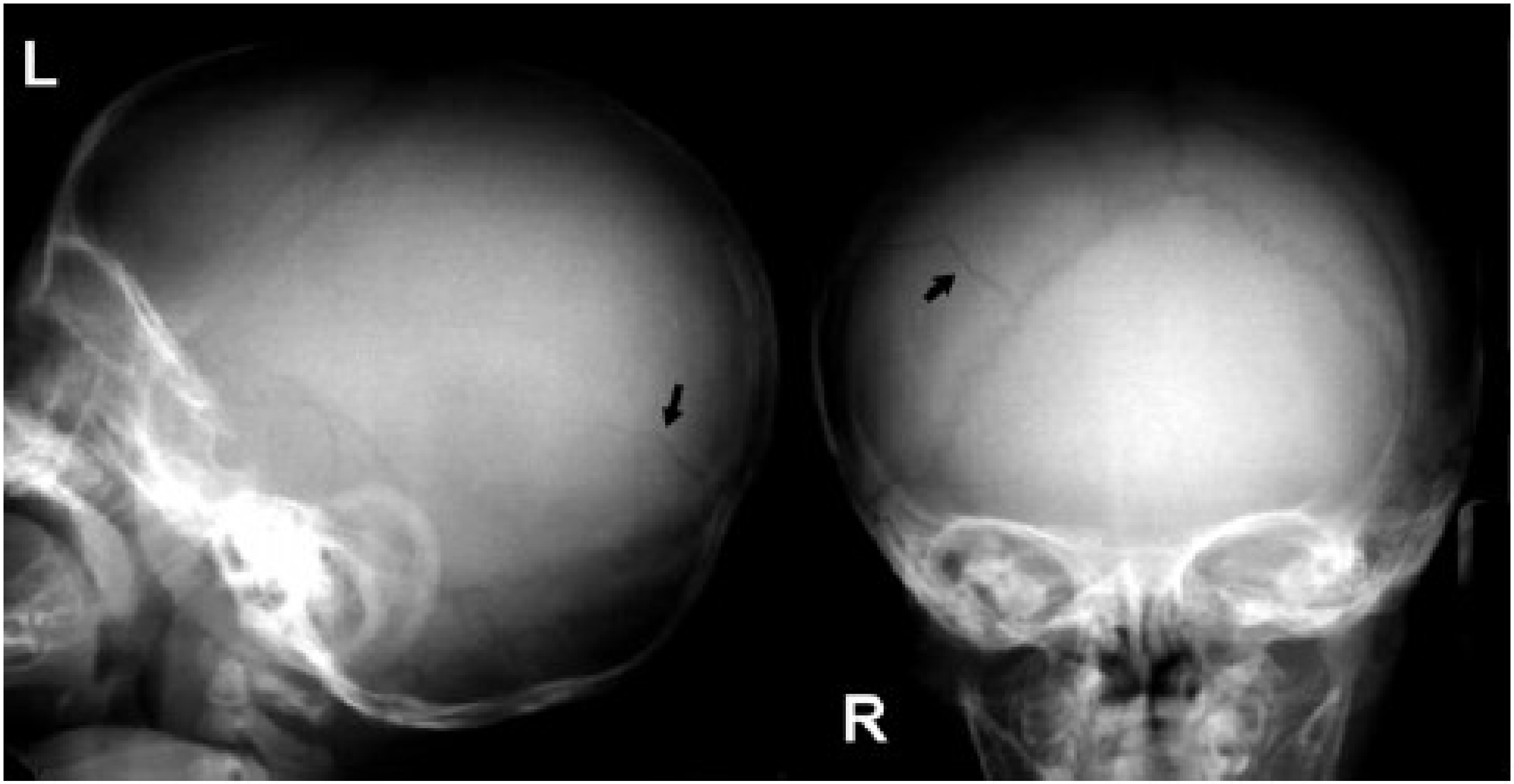
higher absorption by bones due to calcium



bone fracture

skull radiograph

skull radiograph

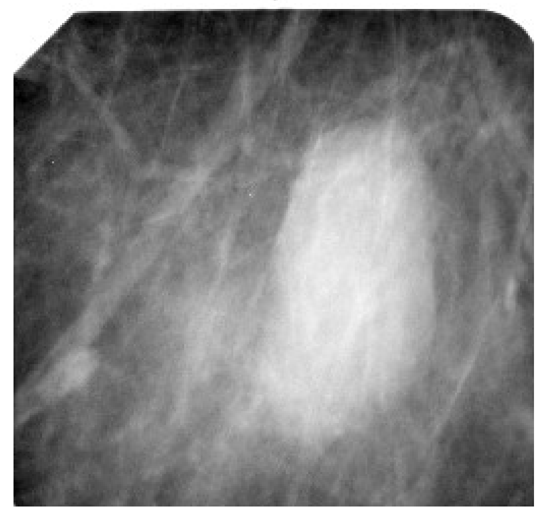


skull fracture

lumbar/cervical spine radiograph

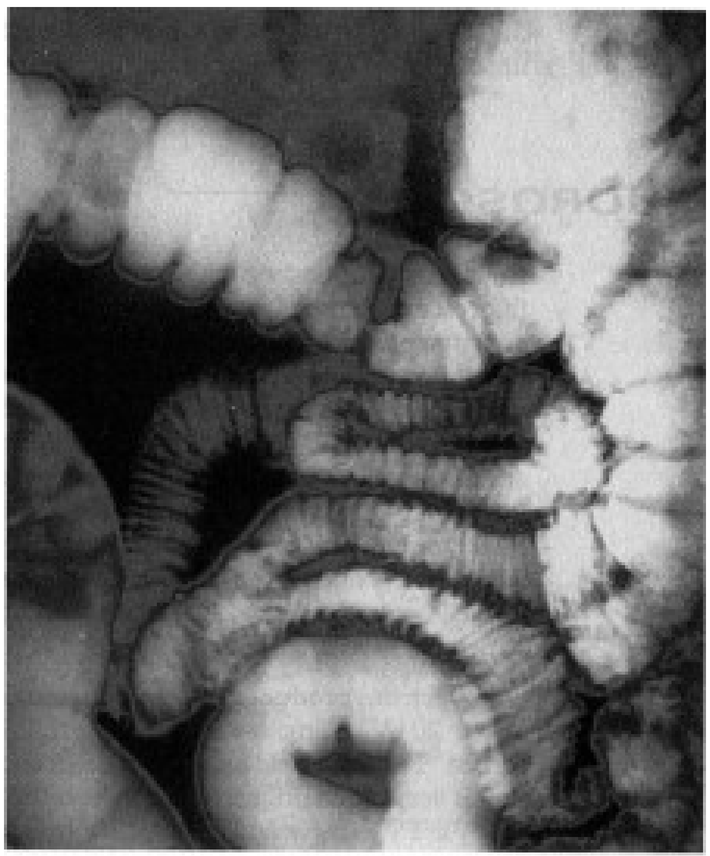
control of implants and splints

mammography



contrast agents

- visualization of vessels
- contrast agents have higher atomic number than biologic environment



x-ray angiography of blood vessels

x-ray image of gastro-intestinal system after intake of a $BaSO_4$-pulp

contrast agents

x-ray negative contrast agents	joints	air, CO_2, N_2O
x-ray negative contrast agents	vessels	triiodobenzoic acid (TIBA) and other
	gastro-intestinal system	$BaSO_4$

contrast agents visualization of vessels

areas of application (iodide- and barium-containing CA):

urogram:	kidneys, urinary tracts
galactography:	mammary ducts
myelography:	spinal cord
cholezystol angiogram:	biliary tracts
sialography:	salivary gland
arthrography:	joints
ERCP:	biliary tracts, pancreas
phlebography:	veins
lymphography:	lymphatic gland and tracts

barium swallow: pharynx, esophagus, small bowel, colon, stomach

projection-radiography

contrast agents **digital subtraction angiography (DSA)**

visualization of vessels without disturbing impact of bones:

- injection of contrast agent (via artery)

- x-ray imaging before and after contrast agent reached organ/area of interest

- “subtraction” of images (computer)

Caveats:

- subtraction of *logarithmized* images leads to clear image of vessel !! (otherwise artifacts, e.g. due to bones)
- movement artifacts !!!

contrast agents **digital subtraction angiography (DSA)**

without CA:

$$J_M = J_0 \cdot e^{-\mu D}$$

where J_M = outgoing intensity (without CA) (M = mask); J_0= ingoing intensity;
$\mu =$ mean attenuation coefficient; D = thickness of object

with CA:

$$J_F = J_0 \cdot e^{-[\mu(D-G)+\mu_J \cdot G]}$$

where J_F = outgoing intensity (with CA) (F = filling); G = thickness of vessel;
$\mu_J =$ mean attenuation coefficient of CA (J = iodide)

log. difference image:

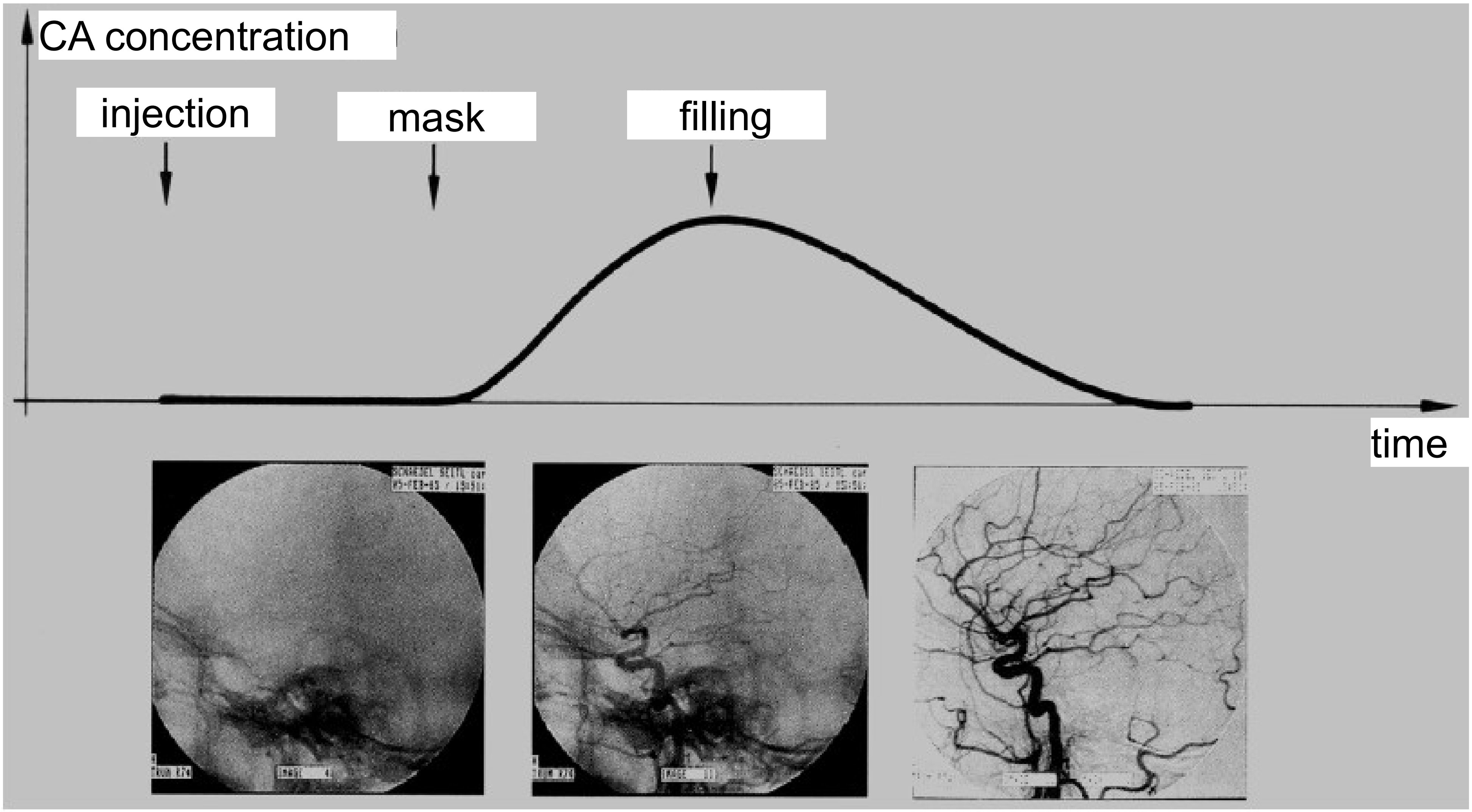
$$\ln J_F - \ln J_M = \ln J_0 - \mu(D-G) - \mu_J G - \ln J_0 + \mu D$$

$$= G(\mu - \mu_J) \approx -G\mu_J \quad \text{(if: } \mu_J >> \mu)$$

grey level depends on thickness of vessel only !!

projection-radiography

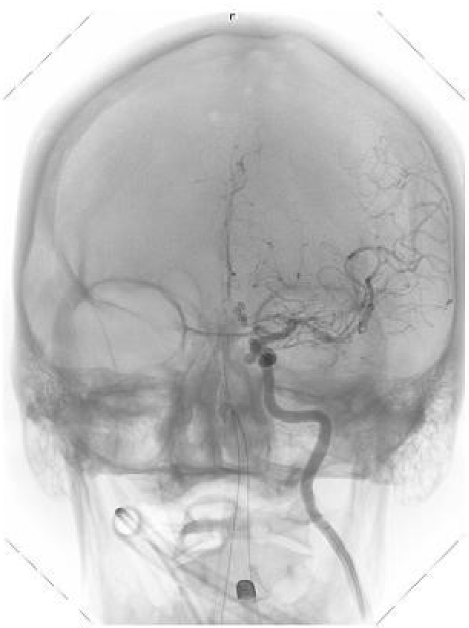
contrast agents — digital subtraction angiography (DSA)



mask filling subtraction

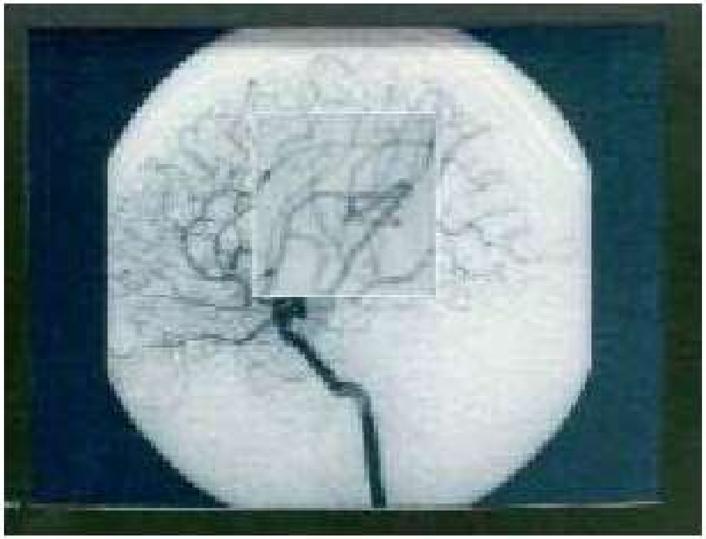
projection-radiography

contrast agents **digital subtraction angiography (DSA)**



contrast agents

digital subtraction angiography (DSA)



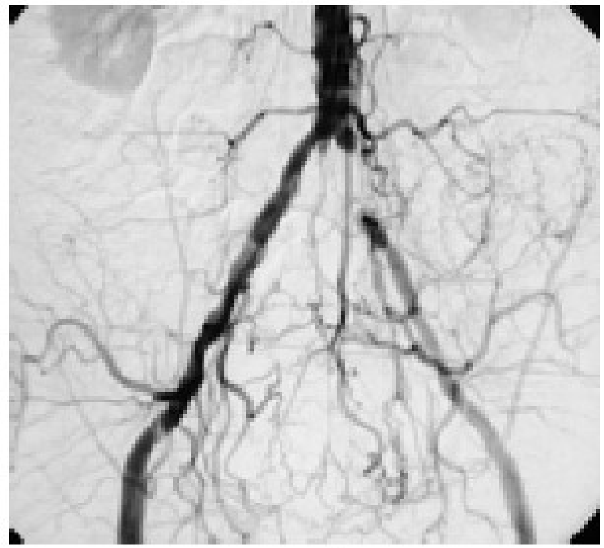
DSA of
a. mesenterica
(branch of
abdominal aorta)

projection-radiography

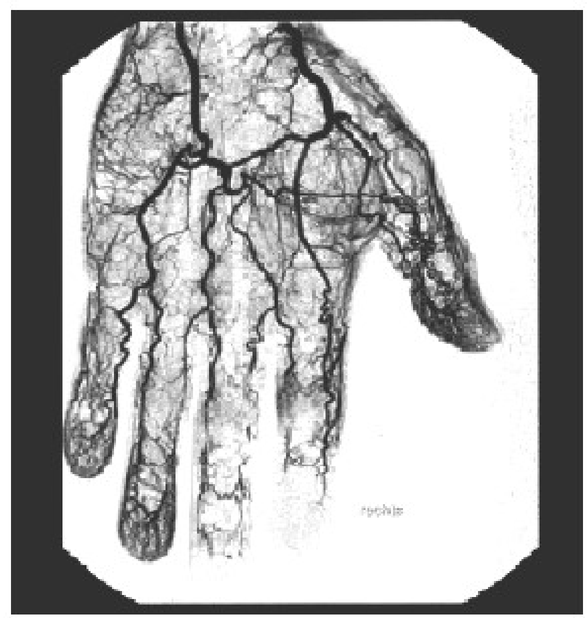
contrast agents

DSA of lung

digital subtraction angiography (DSA)



DSA of pelvis

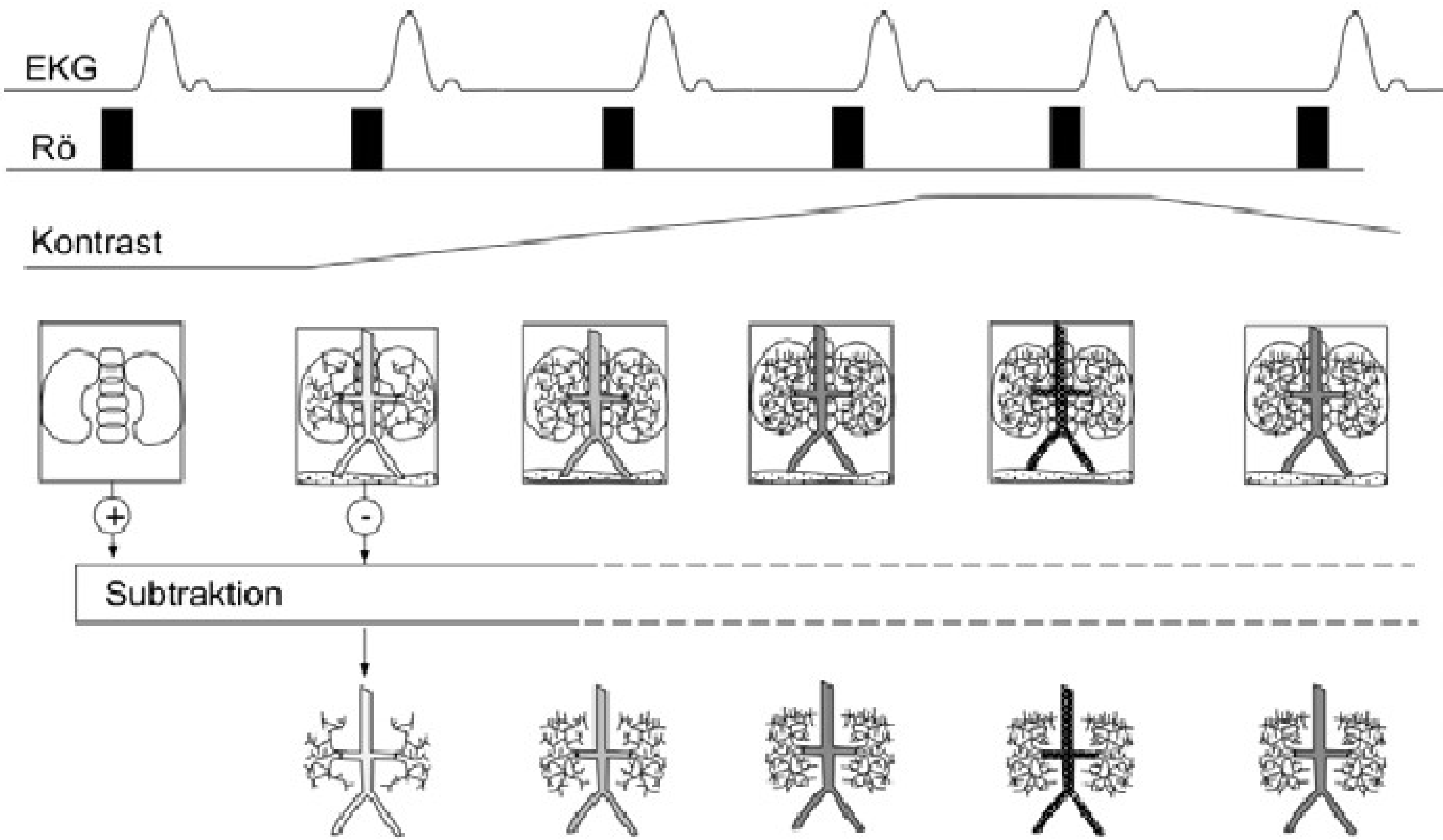


DSA of hand

contrast agents

digital subtraction angiography (DSA)

DSA with EKG-triggering (e.g.: splenic vessels)



projection-radiography

brain	cerebral angiography, cranial vessels, carotid
bones/joints	fracture, osteoporosis, spinal disc, bone tumor, prosthetics, joint cavity (arthography)
blood vessels/heart	angiography (heart, coronary vessels, brain, limbs, kidneys, aortic valve, aortic arch, veins, ventricles of heart
gastro-intestinal tract	appendix, constipation, bowel occlusion, twisting of the bowels
kidney/bladder	splenic vessels, lithotripsy (e.g. renal stones)
breast	mammography (precaution, cancer)
lung	embolism, inflammation, tuberculosis
teeth	dental root, jaw

projection-radiography

summary:

pros:

easy-to-handle, cheap $\Rightarrow$ broad applicability

cons:

ionizing radiation, radiation protection

images not invariant under rotation of object

different soft tissues hard to distinguish

no 3D-information
(overlay of back-to-back objects)