Scanprotocol CT pancreascarcinoom

Bijgaand protocol is een handreiking waarbij ruimte bestaat om deze in uw ziekenhuis aan te passen wanneer het beter kan of anders moet, op basis van de beschikbare apparatuur en/of expertise. De protocollen zijn zoveel mogelijk 'evidence-based' ontwikkeld en aangevuld met 'expert opinion'. Protocollen kunnen op basis van nieuw wetenschappelijk bewijs en inzichten worden geactualiseerd. Meer info: www.radiologen.nl (NVvR, 2019).

Vraagstelling

Welke scantechniek is optimaal voor het stadiëren van een pancreastumor?

Inleiding

Pancreas carcinomen staan op de vierde plaats als het gaat om kanker-gerelateerde mortaliteit. ComputerTomografie (CT) is nog steeds de meest toegankelijke en gevalideerde modaliteit voor diagnostiek. Om snelle en accurate diagnostiek te kunnen toepassen is een adequaat CT Protocol essentieel. Hierdoor kunnen de sensitiviteit en specificiteit ten aanzien van tumor detectie en resectabiliteit worden geoptimaliseerd. Hiervoor werd gekeken naar literatuur, praktische overwegingen en reeds bestaande internationale richtlijnen.

Zoeken en selecteren

In de databases Medline (OVID), Embase and Cochrane is met relevante zoektermen voor CT gezocht naar literatuur over pancreastumoren (geen neuroendocriene tumoren) en CT scanprotocollen.
De literatuurzoekactie leverde 534 treffers op (zie ook de evidence tabel). Studies die voldeden aan de volgende selectiecriteria werden geïncludeerd:

- Vergelijkend onderzoek
- Onderzoek bij volwassen patiënten (18 jaar en ouder)
- Onderzoek over *coupe dikte, scan regio, contrast protocol, scan fasen, type voorbereiding, reconstructies*
- *Rapportage sensitiviteit en specificiteit van de verschillende scanprotocollen met bettrekking tot detectie van de primaire pancreastumor*

Parameters van het CT protocol pancreas

Coupe dikte

Samenvatting literatuur
Er werd geen literatuur (van voldoende kwaliteit) gevonden.

Overwegingen
De geadviseerde coupe dikte in de parenchym fase bedraagt 1 mm met een maximum van 3 mm. Dit om eventuele doorgroei naar omringende (vaat)structuren adequaat te kunnen beoordelen. De geadviseerde coupe dikte in andere fasen bedraagt 3 mm met een maximum van 5 mm. Dit is conform de protocollen zoals beschreven in de literatuur.

Aanbeveling

Coupe dikte van 1 - 3 mm in de parenchym en arteriële fase en 3 - 5 mm in de overige fasen.

Scan regio

Samenvatting literatuur
Er werd geen literatuur (van voldoende kwaliteit) gevonden.
Overwegingen
De scan regio in de blanco, parenchym en arteriële fase betreft de gehele lever en pancreas. Tijdens de portale veneuze fase wordt geadviseerd om in ieder geval de gehele lever en het pancreas te scannen, waarbij overwogen kan worden het gehele abdomen te scannen. Tevens kan overwogen worden om in de portaal veneuze fase de thorax ook mee te scannen ter diagnostisering van (zeldzame) longmetastasen.

Aanbeveling

De scan regio in elke fase betreft de gehele lever en het pancreas. Overwogen kan worden om in de portale veneuze fase de thorax en gehele abdomen te scannen.

Contrastvloeistof [wanneer en hoe, concentratie en hoeveelheid]

Literatuur
Het gebruik van contrastvloeistof met een hogere I concentratie (370 - 400 mg I/mL) en hogere snelheid van toediening (5 - 8 mL/ sec) geeft een betere aankleuring van pancreas parenchym en vaatstructuren.
Bij ouderen (> 60 jaar), kan overwogen worden om de dosis en snelheid van contrastvloeistof toediening te verlagen met 10%. De bewijskracht hiervoor is laag.
Daarnaast wordt geadviseerd om na toediening van de contrastvloeistof een bolus van 20-40 mL NaCl te geven.

Overwegingen
Waar mogelijk wordt een hogere contrast concentratie en snelheid geadviseerd. Er bestaat geen consensus in de literatuur over de totale hoeveelheid contrast. Gebruikelijk is 0,3 - 0,6 g I/kg met een absoluut maximum van 75 g I.
Bij een snellere toediening van contrast komt de timing van scannen zeer nauwkeurig. De bewijskracht voor een toediening snelheid van 8 mL/sec is erg laag. Derhalve wordt een toediening snelheid van 4 - 5 mL/sec geadviseerd.

Aanbeveling

Er wordt geadviseerd om een concentratie van 370 - 400 mg I/mL te gebruiken. Er wordt geadviseerd om een toedieningssnelheid van 4-5 mL / sec te handhaven. Er wordt geadviseerd om een dosering van 0,3 - 0,6 g I/kg te hanteren. Het geven van een NaCl bolus na contrasttoediening wordt geadviseerd.

Scan fasen

Samenvatting literatuur
In de parenchym fase wordt de hoogste differentiatie behaald tussen tumor en normaal parenchym bij de (hypovasculaire) tumoren. Voor het bepalen van vasculaire ingroei heeft de portaal-veneuze fase de hoogste sensitiviteit. De laat veneuze fase kan worden overwogen voor zeldzamere isovasculaire tumoren. De blanco fase kan overwogen worden voor bepaling van densiteit van de tumor en calcificaties in het pancreas.
Het gebruik van bolus-tracking kan de mate van attenuatie van pancreas parenchym en tumor-pancreas differentiatie significant verbeteren.
Daarnaast zijn er aanwijzingen dat split-bolus een vergelijkbare attenuatie en tumor-differentiatie geeft als een meerfasen CT. De bewijskracht is echter laag.

Overwegingen
Bij het kiezen van een scan-delay voor verschillende fasen moet rekening worden gehouden met de snelheid van contrast toediening, de concentratie van het contrast, het al dan niet gebruiken van bolus-tracking, de snelheid van de scanner, de leeftijd van patiënt en het al dan niet aanwezig zijn van cardiovasculair lijden. De werkgroep adviseert om de scan-delay te optimaliseren op basis van bovenstaande factoren.
De arteriële fase bevindt zich circa 10-20 sec na injectie of 5-10 sec na bolus-tracking (HU 100 - 150 t.h.v. truncus coeliacus).
De parenchym fase bevindt zich circa 35-45 sec na injectie of 15-30 sec na bolus-tracking (HU 100 - 150 t.h.v. truncus coeliacus).
De portaal-veneuze fase bevindt zich circa 55-70 sec na injectie of 45-55 sec na bolus-tracking (HU 100 - 150 t.h.v. truncus coeliacus).
De late fase bevindt zich circa 150-240 sec na injectie of 170 sec na bolus-tracking (HU 100 - 150 t.h.v. truncus coeliacus).

Aanbeveling

De parenchym fase en portaal veneuze fase zijn essentieel voor diagnostisering. De timing van verschillende fasen is afhankelijk van meerdere factoren. Bolus-tracking wordt hierbij aangeraden.

Voorbereiding patiënt

Samenvatting literatuur
Geen literatuur (of van onvoldoende kwaliteit).

Overwegingen
Het gebruik van negatief en/of positief oraal contrast als voorbereiding kan worden overwogen. In de literatuur zijn aanwijzingen dat het gebruik van H2O als voorbereiding dezelfde distensie van de darm geeft als oraal contrast; het nadeel van H2O betreft snelle opname door de darm.
Buscopan en secretie worden in de literatuur genoemd als voorbereiding, echter de literatuur behelst onvoldoende bewijskracht om hier een uitspraak over te doen.

Aanbeveling

Het gebruik van oraal contrast in de vorm van water voor adequate distensie van maag en duodenum en/of jodium-houdend contrast als darmvoorbereiding kan worden overwogen.

Reconstructies

Samenvatting literatuur

Het gebruik van Multi-Planar Reconstructies (MPR) in combinatie met axiale beelden verbetert de detectie van pancreas carcinomen significant. Echter bij de beoordeling van de vaat-ingroei heeft het gebruik van MPR beelden een hoge inter-observator variabiliteit.
Het gebruik van virtuele technieken om een blanco-scan te reconstrueren geeft een vergelijkbare kwaliteit als een blanco scan en kan worden gebruikt om een dosis reductie te bewerkstelligen.

Overwegingen

Het gebruik van (curved) MPR kan een toegevoegde waarde hebben boven op alleen axiale opnamen.
Virtuele beelden kunnen worden gebruikt om de blanco-scan te vervangen, de bewijskracht is echter zeer laag. Daarnaast kan worden geopteerd om de blanco-scan in zijn geheel weg te laten. Het bepalen van een “central luminal line” door vena portae en VMS kan worden overwogen.

Aanbeveling

Multi-planar reconstructies kunnen worden overwogen.

Straling

Samenvatting literatuur

Het gebruik van een lage buisspanning (80 kVp) geeft een betere tumor waarneembaarheid en een betere attenuatie van pancreas, vena portae en aorta en een betere pancreas-tumor differentiatie met een significante verlaging van de effectieve dosis (van circa 18,5 naar 5,1 mSv) dan een protocol met een hogere buisspanning (120 kVp of 140 kVp). Het nadeel vaan een lagere buisspanning is een meer ruis.
Iteratieve reconstructies kunnen een aanzienlijke dosis reductie van 36 - 60% bewerkstelligen door het verlagen van ruis bij gebruik van lagere kV.
Overwegingen

Indien beschikbaar kunnen iteratieve reconstructies een aanzienlijke dosis-reductie of kwaliteit verbetering opleveren. Het gebruik wordt aangeraden.

Het gebruik van een lage buisspanning en hoge buisstroom kan worden overwogen.

Aanbeveling

Het gebruik van een lage buisspanning en hoge buisstroom kan worden overwogen.
Iteratieve reconstructies worden sterk aangeraden.

Aanbevolen scanprotocol

Bovenstaande overwegingen en de resultaten van de literatuuranalyse leiden tot onderstaand aanbevolen scanprotocol.

- **Specificaties Standaard CT scanprotocol**

Sequence	**Blanco**	**parenchym fase**	**Porto-veneuze fase**
Position/Landmark	Pancreas + Lever	Pancreas + Lever	Pancreas + Lever ± Onderbuik
Topogram Direction	Cranio-caudaal	Cranio-caudaal	Cranio-caudaal
Respiratory Phase	Inspiration	Inspiration	Inspiration
Scan Type	helical	helical	helical
KV / mA / Rotation time (sec) **Pitch / Speed (mm/rotation)** **Noise Index / ASiR / Dose Reduction**	80 - 140 kV / Automatisch / 0,5 sec / Standaard / scanner afhankelijk / - / IR / FBP	80 - 140 kV / Automatisch / 0,5 sec / Standaard / scanner afhankelijk / - / IR / FBP	80 - 140 kV / Automatisch / 0,5 sec / Standaard / scanner afhankelijk / - / IR / FBP
Slice Thickness/ Spacing **Algorithm** **Recon Destination**	3 - 5 mm	1 - 3 mm	2 - 3 mm
Detector width x Rows = Beam Collimation	-	-	-
Average Tube Output	-	-	-
Scan Start / End Locations DFOV	-	-	-
IV Contrast Volume / Type / Rate		0,3 - 0,6 mg/kg / 370 - 400 mg I/mL / 4 - 5 mL/sec	0,3 - 0,6 mg/kg / 370 - 400 mg I/mL / 4 - 5 mL/sec
Scan Delay	-	15 - 30 sec na bolus tracking	45 - 55 sec na bolus tracking

		35 - 45 sec na injectie	55 - 70 sec na injectie
2D/3D Technique Used	-	MPR	MPR
≅Time	-	-	-

Specificaties Additioneel CT scanprotocol
Additioneel kan worden gekozen voor het toevoegen van de thorax in de blanco of veneuze fase. Tevens kunnen een arteriële of late fase worden overwogen.

Sequence	**Arteriële fase**	**Late fase**
Position/Landmark	Pancreas + Lever ± Onderbuik	Pancreas + Lever ± Onderbuik
Topogram Direction	Cranio-caudaal	Cranio-caudaal
Respiratory Phase	Inspiration	Inspiration
Scan Type	helical	helical
KV / mA / Rotation time (sec) **Pitch / Speed (mm/rotation)** **Noise Index / ASiR / Dose Reduction**	80 - 140 kV / Automatisch / 0,5 sec / Standaard / scanner afhankelijk / - / IR / FBP	80 - 140 kV / Automatisch / 0,5 sec / Standaard / scanner afhankelijk / - / IR / FBP
Detector width x Rows = Beam Collimation	1 - 3 mm	3 - 5 mm
Average Tube Output	-	-
Scan Start / End Locations DFOV	-	-
IV Contrast Volume / Type / Rate	-	-
Scan Delay	5 - 10 sec na bolus tracking 5 - 10 sec na injectie	170 sec na bolus tracking 150 - 240 sec na injectie
2D/3D Technique Used	-	-
≅Time	-	-

Literatuur

- Baek S, et al. Two-dimensional multiplanar and three-dimensional volume-rendered vascular CT in pancreatic carcinoma: interobserver agreement and comparison with standard helical techniques. AJR Am J Roentgenol. 2001 Jun;176(6):1467-73.
- Brook O, et al. Split-Bolus Spectral Multidetector CT of the Pancreas: Assessment of Radiation Dose and Tumor Conspicuity. Radiology 2013; 2013 Oct; 269(1):139-48.
- Catalano C, et al. Pancreatic carcinoma: the role of high-resolution multislice spiral CT in the diagnosis and assessment of resectability. Eur Radiol (2003) 13:149–156.
- Choi J, et al. Iterative reconstruction algorithms of computed tomography for the assessment of small pancreatic lesions: phantom study. J Comput Assist Tomogr. 2013 Nov-Dec;37(6):911-23.
- Chu AJ, Lee JM, Lee YJ, Moon SK, Han JK, Choi BI. Dual-source, dual-energy multidetector CT for the evaluation of pancreatic tumours. Br J Radiol. 2012 Oct;85(1018):e891-8. doi: 10.1259/bjr/26129418.
- Clark Z, et al. Abdominal rapid-kVp-switching dual-energy MDCT with reduced IV contrast compared to conventional MDCT with standard weight-based IV contrast: an intra-patient comparison. Abdom Imaging. 2015 Apr;40(4):852-8.
- Engeroff B, et al. Impact of different iodine concentrations on abdominal enhancement in biphasic multislice helical CT (MS-CT). Rofo. 2001 Oct;173(10):938-41.
- Fenchel S, et al. Effect of iodine concentration of contrast media on contrast enhancement in multislice. Br J Radiol. 2004 Oct;77(922):821-30.
- Fletcher J, et al. Pancreatic malignancy: value of arterial, pancreatic, and hepatic phase imaging with multi-detector row CT. Radiology. 2003 Oct;229(1):81-90.
- Fukukura Y, et al. Pancreatic adenocarcinoma: a comparison of automatic bolus tracking and empirical scan delay. Abdom Imaging. 2010 Oct;35(5):548-55.
- Fukushima H, et al. Diagnostic value of curved multiplanar reformatted images in multislice CT for the detection of resectable pancreatic ductal adenocarcinoma. Eur Radiol. 2006 Aug;16(8):1709-18.
- Goshima S, et al. Pancreas: optimal scan delay for contrast-enhanced multi-detector row CT. Radiology. 2006 Oct;241(1):167-74.
- Hata H, et al. Fibrous stroma and vascularity of pancreatic carcinoma: correlation with enhancement patterns on CT. Abdom Imaging. 2010 Apr;35(2):172-80.
- Holm J, et al. Low tube voltage CT for improved detection of pancreatic cancer: detection threshold for small, simulated lesions. BMC Med Imaging. 2012 Jul 24;12:20.
- Ichikawa T, et al. MDCT of pancreatic adenocarcinoma: optimal imaging phases and multiplanar reformatted imaging. AJR Am J Roentgenol. 2006 Dec;187(6):1513-20.
- Imbriaco M, et al. Value of the single-phase technique in MDCT assessment of pancreatic tumors. AJR Am J Roentgenol. 2005 Apr;184(4):1111-7.
- Ishigami K, Yoshimitsu K, Irie H, Tajima T, Asayama Y, Nishie A, Hirakawa M, Ushijima Y, Okamoto D, Nagata S, Nishihara Y, Yamaguchi K, Taketomi A, Honda H. Diagnostic value of the delayed phase image for iso-attenuating pancreatic carcinomas in the pancreatic parenchymal phase on multidetector computed tomography. Eur J Radiol. 2009 Jan;69(1):139-46. Epub 2007 Oct 24.
- Itoh S, et al. The effect of patient age on contrast enhancement during CT of the pancreatobiliary region. AJR Am J Roentgenol. 2006 Aug;187(2):505-10
- Kondo H, et al. MDCT of the pancreas: optimizing scanning delay with a bolus-tracking technique for pancreatic, peripancreatic vascular, and hepatic contrast enhancement. AJR Am J Roentgenol. 2007 Mar;188(3):751-6.
- Makarawo T, et al. Water as a contrast medium: a re-evaluation using the multidetector-row computed tomography. Am Surg. 2013 Jul;79(7):728-33.
- Marin D, et al. Detection of pancreatic tumors, image quality, and radiation dose during the pancreatic parenchymal phase: effect of a low-tube-voltage, high-tube-current CT technique--preliminary results. Radiology. 2010 Aug;256(2):450-9.
- McNulty N, et al. Multi--detector row helical CT of the pancreas: effect of contrast-enhanced multiphasic imaging on enhancement of the pancreas, peripancreatic vasculature, and pancreatic adenocarcinoma. Radiology. 2001 Jul;220(1):97-102.
- Mileto A, Mazziotti S, Gaeta M, Bottari A, Zimbaro F, Giardina C, Ascenti G. Pancreatic dual-source dual-energy CT: is it time to discard unenhanced imaging? Clin Radiol. 2012 Apr;67(4):334-9.
- Noda Y, et al. Reduction of iodine load in CT imaging of pancreas acquired with low tube voltage and an adaptive statistical iterative reconstruction technique. J Comput Assist Tomogr 2014;38: 714–720.
- O'Connell A, et al. Secretin-assisted CT of the pancreas: improved pancreatic enhancement and tumour conspicuity. Clin Radiol. 2008 Apr;63(4):401-6.

- Patel B, et al. Single-source dual-energy spectral multidetector CT of pancreatic adenocarcinoma: optimization of energy level viewing significantly increases lesion contrast. Clin Radiol. 2013 Feb;68(2):148-54
- Schoellnast H, et al. Improvement of parenchymal and vascular enhancement using saline flush and power injection for multiple-detector-row abdominal CT. Eur Radiol. 2004 Apr;14(4):659-64.
- Schueller G, Schima W, Schueller-Weidekamm C, Weber M, Stift A, Gnant M, Prokesch R. Multidetector CT of pancreas: effects of contrast material flow rate and individualized scan delay on enhancement of pancreas and tumor contrast. Radiology. 2006 Nov;241(2):441-8.
- Stuber T, et al. Sixty-four MDCT achieves higher contrast in pancreas with optimization of scan time delay. World J Radiol. 2012 Jul 28;4(7):324-7.
- Tang A, et al. Optimal Pancreatic Phase Delay with 64-Detector CT Scanner and Bolus-tracking Technique. Acad Radiol. 2014 Aug;21(8):977-85.
- Yamamura S, et al. Dynamic computed tomography of locally advanced pancreatic cancer: effect of low tube voltage and a hybrid iterative reconstruction algorithm on image quality. J Comput Assist Tomogr. 2013 Sep-Oct;37(5):790-6.
- Zamboni G, et al. Single-energy low-voltage arterial phase MDCT scanning increases conspicuity of adenocarcinoma of the pancreas. Eur J Radiol. 2014 Mar;83(3):e113-7.

Bijlagen

Zoekverantwoording

Database	Zoektermen	Totaal
Medline (OVID) 2000-juni 2015 Engels, Nederlands, Duits, Frans	25 exp Pancreatic Neoplasms/ (58387) 26 (((pancrea* or neuroendocrin*) adj3 (tumo?r or cancer* or carcinoma* or neoplasm* or malignan* or adenocarcinom*)) or (duct* adj3 adenocarcinoma*) or pancreas).ti,ab. (118806) 27 25 or 26 (136215) 28 exp Tomography, X-Ray Computed/ (320764) 29 (((Multidetector or multirow or "contrast enhanced") adj3 ("computed tomograph*" or CT or CTA)) or MDCT).ti,ab. (16857) 30 28 or 29 (324684) 31 27 and 30 (8098) 32 24 and 31 (22) 33 (recommend* or consensus*).ti. (46600) 34 guideline*.ab. /freq=2 (46551) 35 guideline*.ti. or (ACR adj3 criteria).ti,ab. (55364) 36 Guideline/ or Practice Guideline/ or guidelines as topic/ or practice guidelines as topic/ (143915) 37 protocol*.ti,ab. (281988) 38 Clinical Protocols/ (21099) 39 "Societies, Medical"/ (54655) 40 algorithms/ or algorithm*.ti,ab. (266330) 41 technical report.pt. (2339) 42 (enhancement or standard* or value).ti. or optimal.ti,ab. (471631)	534

	43 or/33-42 (1222723) 44 31 and 43 (767) 45 24 and 44 (22) 46 limit 44 to (yr="2000 -Current" and (dutch or english or french or german)) (543) – 534 uniek	

Evidencetabel

Reference	Study Type	Patients/ events	Objective	Results	Study Quality
Baek, 2001	Retro	44 pts, 56 scans	The purpose of this study was to compare two-dimensional curved multiplanar and three-dimensional reconstructions, routine axial presentations, and combined techniques in the assessment of vascular involvement by pancreatic malignancy.	Intraobserver agreement averaged over five vessels was good between the axial and combined techniques for each individual observer (0.64 < or kappa < or = 0.66), but intraobserver agreement was poor between the axial and reformatted (kappa = 0.17 and kappa = 0.31, respectively) and the reformatted and combined techniques (kappa = 0.31 and kappa = 0.38, respectively) for two observers. For grading of vascular involvement in each vessel, intraobserver agreement was good to excellent between the axial and combined techniques (0.48 or = kappa < or = 0.82). Interobserver agreement averaged over five vessels was poor for imaging techniques except between observer 2 and observer 3 on the axial (kappa = 0.47) and combined techniques (kappa = 0.47). For grading of vascular involvement in each vessel, interobserver agreement for reformatted technique was poor (0.09 < or = kappa < or = 0.40).	Low
Brook, 2013	Retro	163 pts	To assess tumor conspicuity and radiation dose with a new multidetector computed tomography (CT) protocol for pancreatic imaging that combines spectral CT and split-bolus injection.	Tumor conspicuity and CNR were higher with the 60-keV split-bolus protocol (89.1 HU ± 56.6 and 8.8 ± 6.2, respectively) than with the pancreatic or portal venous phase of the standard protocol (43.5 HU ± 28.4 and 4.5 ± 3.0, and 51.5 HU ± 30.3 and 5.6 ± 4.0, respectively; P < .01 for all comparisons). Dose-length product was 1112 mGy · cm ± 437 with the standard protocol and 633 mGy · cm ± 105 with the split-bolus protocol (P < .001).	Low
Catalano, 2003	Pro	46 pts	The purpose of our study was to evaluate multislice computed tomography (MSCT) in the assessment of patients with clinical, laboratory, and US suspicion of pancreatic neoplasm, and to evaluate respectability status.	The evaluation of all images provided a diagnosis in 44 patients, with a sensitivity, specificity, and accuracy of 97, 80, and 96%, respectively. The MSCT correctly provided a diagnosis of unresectability with sensitivity of 96%, specificity of 86%, and accuracy of 93%. Evaluation of 1-mm slices demonstrated 83 of the 91 liver metastases found at surgery; conversely, the 5-mm slices detected only 76 of these lesions. Infiltration of peripancreatic major vessels was demonstrated, and was confirmed at surgery in 18 patients.	Low

Choi, 2013	Pro	4 scanners	To evaluate the image quality and radiation dose reduction of iterative reconstruction (IR) used for computed tomographic (CT) scanning of small pancreatic lesions.	Image noise was markedly improved with the IR; therefore, a 36 to 60% dose reduction was possible. As a result, the final CT dose index volume can be diminished to 7.05 to 11.40 mGy with the IR algorithms. The IR demonstrated 1.52 to 7.84 times higher FOM than that of FBP. Particularly, an advanced fully IR showed outstanding results of FOM (6.06-7.84 times).	Low
Chu, 2012	Retro	44 pts	To investigate the potential diagnostic value of dual-energy CT (DECT) with virtual non-enhanced (VNE) and iodine-only images, and to determine the optimal mixed ratio of blended images for evaluation of pancreatic diseases.	The level of acceptance of the VNE images in replacing TNE images was 90.9%. Regarding the iodine-only images, 50% of the cases were found to have an added value. The linear-blended images with a weighting factor of 0.5 were preferred.	Low
Clark, 2015	Retro	24 pts (29 scans)	Perform intra-patient comparison of attenuation values on lower keV dual-energy abdominal CT images using reduced IV contrast dose compared to conventional single energy polychromatic beam abdominal MDCT images using standard IV contrast dose.	Mean reduction in IV contrast dose was 37 %. Mean ± SD HU on 52 keV rsDECT vs. SECT were: aorta 534 ± 138 vs. 271 ± 69; liver 88 ± 24 vs. 67 ± 16; pancreas 140 ± 60 vs. 89 ± 40; psoas 63 ± 15 vs. 50 ± 12 (all $p < 0.001$). Noise was higher for 52 keV compared to SECT ($p < 0.001$); CNRs were not significantly different. Mean ± SD DLP for rsDECT was 1421 ± 563 and SECT 1335 ± 562 mGy·cm ($p = 0.640$). For tumor vs. nontumoral parenchyma, mean absolute contrast difference was 58.4 HU on 52 keV, and 29.0 HU on SECT. Nearly all images were rated as good or excellent and there were no statistically significant differences in image quality between the DECT and SECT images.	Low
Engeroff, 2001	Pro	75 pts	To evaluate if different iodine concentrations of a contrast material (c.m.) have an impact on abdominal enhancement in MS-CT during the arterial (AP) and portal venous phase (PVP).	The comparison of the three groups showed an improved enhancement in aorta, spleen, and pancreas during the AP by using the higher c.m. concentrations. In the PVP the c.m. enhancement of aorta, liver, spleen, and pancreas was independent of the administered c.m. concentration.	Low
Fenchel, 2004	RCT	50 pts	The purpose of this study was to determine the influence of two different iodine concentrations of the non-ionic contrast agent, Iomeprol, on contrast enhancement in multislice CT (MSCT) of the pancreas.	Iomeprol 400 led to a significantly greater enhancement in the aorta, superior mesenteric artery, coeliac trunk, pancreas, pancreatic carcinomas, kidneys, spleen and wall of the small intestine than Iomeprol 300. Portal venous phase enhancement was significantly greater in the pancreas, pancreatic carcinomas, wall of the small intestine and portal vein with Iomeprol 400. The two independent readers considered Iomeprol 400 superior over Iomeprol 300 concerning technical quality, contribution of the contrast agent to the diagnostic value, and evaluability of vessels in the arterial phase. No differences were found for tumour delineation and evaluability of infiltration of organs adjacent to the pancreas between the two iodine concentrations. In conclusion the higher iodine concentration leads to a higher arterial phase contrast enhancement of large and small arteries in MSCT of the pancreas and therefore improves the evaluability of vessels in the arterial phase.	High

Fletcher, 2003	Pro	39 pts	To assess the value of arterial, pancreatic, and hepatic phase imaging at multi-detector row computed tomography (CT) of the pancreas for pancreatic malignancy.	Mean tumor-to-gland attenuation difference was greatest on images obtained in the pancreatic phase (42 HU) versus that on those obtained in the hepatic phase (35 HU) and in the arterial phase (25 HU). For tumor detection, sensitivity of the images obtained in pancreatic (0.97 [29 of 30]) and hepatic (0.93 [28 of 30]) phases was superior to that of those obtained in arterial phase (0.63 [19 of 30]) (P < or =.008). For vascular invasion detection, sensitivity of images obtained in the hepatic phase (0.83) was better than that of those obtained in the pancreatic (0.58) and arterial (0.25) phases. Images obtained in the pancreatic phase demonstrated more flow artifacts and decreased attenuation in the superior mesenteric vein, compared with the artifacts revealed on images obtained in the hepatic phase.	Low
Fukukura, 2010	Pro	79 pts	To evaluate the efficacy of automatic bolus tracking in multidetector row CT (MDCT) for pancreatic adenocarcinoma as compared with standard scan delay using the fixed duration contrast injection technique.	Pancreatic parenchymal enhancement (mean ± standard deviation, 100.2 HU ± 17.6 vs. 88.5 HU ± 22.1; P < 0.05) and tumor-to-pancreas contrast (mean ± standard deviation, 75.3 HU ± 25.0 vs. 63.1 HU ± 24.1; P < 0.05) were significantly greater in protocol 1 than in protocol 2 during pancreatic parenchymal phase. Qualitative results correlated well with quantitative results (reviewer 1: R (s) = 0.78, P < 0.001; reviewer 2: R (s) = 0.66, P < 0.001).	Average
Fukushima, 2006	Pro	50 pts	The purpose of this study was to assess the usefulness of curved multiplanar reformatted (MPR) images obtained by multislice CT for the depiction of the main pancreatic duct (MPD) and detection of resectable pancreatic ductal adenocarcinoma.	The depiction of the MPD and the diagnostic performance for the detection of carcinoma were statistically compared among these images. MPR images were significantly superior to axial images in depicting the MPD, and the use of both axial and MPR images resulted in further significant improvements. For the detection of carcinoma, MPR images were equivalent to axial images, and the diagnostic performance was significantly improved by the use of both axial and MPR images. High-resolution curved MPR images can improve the depiction of the MPD and the diagnostic performance for the detection of carcinoma compared with axial images alone.	Low
Goshima, 2006	Pro	191 pts	To prospectively determine optimal scan delays for multiphasic contrast medium-enhanced imaging of the pancreas with multi-detector row computed tomography (CT).	Pancreatic parenchyma enhanced most intensely at 35-45 seconds (P < .001) with a peak enhancement at the mean of 40 seconds. Liver parenchyma enhanced most intensely at 55-65 seconds with a peak at 60 seconds (P < .001). The mean time to peak enhancement was 45 seconds for the splenic vein and 55 seconds for the superior mesenteric vein. Qualitative results were in good agreement with quantitative results (both P < .001).	Average
Hata, 2010	Pro	21 pts	To demonstrate the contrast-enhancement behavior of pancreatic carcinoma on dynamic contrast-enhanced CT (DCE-CT), and the relationship between the degree of contrast-enhancement and the vascularity (vessel density) and amount of fibrous stroma (fibrosis within the tumor) on pathological specimen.	All but one patient exhibited a gradually increasing enhancement, but there was considerably wide range in contrast-enhancement values of tumors. Examination of the overall relationship between vascularity and fibrous stroma with contrast-enhancement behavior showed that tumor with more fibrosis and higher vascularity had a higher contrast effect through all phases of dynamic study. Tumors having liver metastases tended to be less fibrotic than tumors without liver metastases.	Low

Holm, 2012	Pro	100 cases	To investigate the effect of decreasing the tube voltage from 120 to 80 kV on the detection of pancreatic tumors.	The highest reader averaged figure-of-merit (FOM) was achieved for 80 kV and 675 mA (FOM=0,850), and the lowest for 120 kV (FOM=0,709). There was a significant difference between the three protocols (p<0,0001), when making an analysis of variance (ANOVA). Post-hoc analysis (students t-test) shows that there was a significant difference between 120 and 80 kV, but not between the two levels of tube currents at 80 kV.	Low
Ichikawa, 2006	Pro	66 pts	The objective of our study was to evaluate the individual contributions of arterial, pancreatic parenchymal, and portal venous phase (PVP) images and the utility of coronal and sagittal multiplanar reformatted (MPR) images in the assessment of pancreatic adenocarcinoma using triple-phase MDCT.	Regarding tumor detection, the image set composed of coronal and sagittal MPR images and of axial images obtained in all phases had a significantly higher value for the area under the ROC curve (A(Z), 0.98 +/- 0.01) than the other image sets and yielded the highest sensitivity (93.5%). The sensitivity of the arterial phase image set (80.6%) was significantly lower than that of all other image sets. Whereas the image set composed of coronal and sagittal MPR images and axial images obtained in all phases yielded the highest kappa values for all local extension factors evaluated, the image set composed of only arterial phase images yielded the lowest kappa values for almost all of the factors.	Average
Imbriaco, 2005	Pro	71 pts	The purpose of our study was to determine the diagnostic value of single-phase MDCT in patients with suspected pancreatic carcinoma.	The mean tumor size was 2.4 cm (range, 4-1 cm). Values for the area under the curve (A(z)) for the assessment of tumor detection were 0.97 for reviewer 1 and 0.96 for reviewer 2 (p = not significant). A(z) values for tumor resectability were 0.90 for reviewer 1 and 0.90 for reviewer 2 (p = not significant). No statistically significant differences were observed between superior mesenteric artery and vein opacification with the hepatic parenchyma enhanced at a time closer to the peak hepatic enhancement, optimizing the detection of hepatic lesions.	Average
Ishigami, 2009	Retro	57 scans	To assess the value of the delayed phase (DP) in pancreatic carcinomas which appear iso-attenuating in the pancreatic parenchymal phase (PPP).	Eight cases (14.0%) showed iso-attenuation and 49 showed hypo-attenuation in the PPP. The DP images revealed seven of eight (87.5%) iso-attenuating tumors to be hyper-attenuating. The size of iso-attenuating tumors was smaller than that of hypo-attenuating tumors (mean+/-S.D.: 12.4+/-4.8mm vs. 30.3+/-9.0mm, p<0.0001). In hypo-attenuating tumors, TPC in the PPP (60.2+/-24.6 HU) was higher than those in the portal venous phase (PVP, 40.5+/-23.0 HU, p<0.0001) and DP (18.3+/-11.8 HU, p<0.0001). In contrast, in iso-attenuating tumors, TPC in the DP (26.0+/-4.9 HU) was higher than those in the PPP (9.2+/-3.7 HU, p=0.0003) and PVP (7.1+/-4.7 HU, p=0.001) phases.	Low
Itoh, 2006	Pro	112 pts	The objective of our study was to assess whether it is possible to reduce the dose and rate of contrast material injection in elderly patients in triple-phase contrast-enhanced CT of the pancreatobiliary region with an MDCT scanner.	Contrast enhancement in the main phases for all organs was significantly more intense in group 2 than in groups 1 and 3. Cases in which pancreatic enhancement in the pancreatic phase was graded as excessive were more frequently observed in group 2. No statistically significant differences were observed between groups 1 and 3 in either quantitative or visual assessment for enhancement of any organ in any phase.	Low (no well defined end-parameters)

Kondo, 2007	RCT	170 pts	The purpose of this study was to determine the optimal MDCT scanning delay for peripancreatic arterial, pancreatic parenchymal, peripancreatic venous, and hepatic parenchymal contrast enhancement with a bolus-tracking technique.	Mean contrast enhancement in the aorta (change in attenuation, 321-327 H) and the superior mesenteric artery (change in attenuation, 304-307 H) approached peak enhancement 5-10 seconds after bolus tracking was triggered. Pancreatic parenchyma became most intensely enhanced (change in attenuation, 84-85 H) 15-20 seconds after triggering, and then the enhancement gradually decreased. Enhancement of the splenic vein and portal vein peaked 25 seconds and that of the superior mesenteric vein peaked 30 seconds after triggering. Liver parenchyma reached 52 H 30 seconds after triggering and reached a plateau (change in attenuation, 58-61 H) at a further scanning delay of 45-55 seconds. Qualitative results were in good agreement with quantitative results.	High
Makarawo, 2013	Retro	66 pts	To re-evaluate differences in image quality, we studied image clarity and luminal distention between the same group of patients who received both a pancreas protocol CT (PPCT) that uses oral water and a conventional positive oral contrast scan.	In comparing the mean radiation dosage, there was no statistical difference between the two protocols, and there was good interrater association with ratios of 0.595 and 0.51 achieved for the PPCT and conventional oral scan, respectively. The Wilcoxon signed-rank test showed statistical differences in the stomach ($P < 0.001$) for both clarity ($P < 0.001$) and distention ($P < 0.001$), the duodenum for both clarity ($P < 0.001$) and distention ($P = 0.02$), and the ileum for distention ($P = 0.02$) with the PPCT having a better median score for organ clarity in the stomach and duodenum and better luminal distention in the stomach, equal distention in the duodenum, and slightly worse distention in the ileum. For the remainder of the bowel and organs evaluated, there was no statistically significant difference in the ratings between the two protocols.	Low
Marin, 2010	Pro	27 pts	To intraindividually compare a low-tube-voltage (80 kVp), high-tube-current (675 mA) computed tomographic (CT) technique with a high-tube-voltage (140 kVp) CT protocol for the detection of pancreatic tumors, image quality, and radiation dose during the pancreatic parenchymal phase.	Compared with protocol A (140 kVp and 385 mA), protocol B (80 kVp and 675 mA) yielded significantly higher contrast enhancement for the aorta (508.6 HU vs 221.5 HU, respectively), pancreas (151.2 HU vs 67.0 HU), and portal vein (189.7 HU vs 87.3 HU), along with a greater pancreas-to-tumor CNR (8.1 vs 5.9) ($P < .001$ for all comparisons). No statistically significant difference in tumor detection was observed between the two protocols. Although standard deviation of image noise increased with protocol B (11.5 HU vs 18.6 HU), this protocol significantly reduced the effective dose (from 18.5 to 5.1 mSv; $P < .001$).	Low
McNulty, 2001	Pro	77 pts (29 adenoca)	To determine the optimal phase for enhancement of the normal pancreas and peripancreatic vasculature and the maximal tumor-to-pancreatic parenchymal enhancement difference by using multiphase, contrast material-enhanced, multi-detector row helical computed tomography (CT).	Maximal enhancement of the normal pancreatic parenchyma occurred during the PPP. Maximal tumor-to-parenchyma attenuation differences during the PPP and PVP were equivalent but greater than that during the AP. Subjective analysis revealed that tumor conspicuity during the PPP and PVP was equivalent but superior to that during the AP. Maximal arterial enhancement was seen during the PPP, and maximal venous enhancement was seen during the PVP.	Laag

Mileto, 2012	Pro	51 pts	To compare pancreatic virtual unenhanced (VUE) and true unenhanced (TUE) images and to calculate the potential dose reduction by omitting the conventional unenhanced scan.	Mean TUE and VUE IQ were 1.5 ± 0.6 and 1.6 ± 0.6 (k = 0.891), with no significant difference (p > 0.05). Mean TUE and VUE IN were 12.3 ± 1.6 and 10.3 ± 1.5 HU, and resulted significantly different (p < 0.001). Mean effective doses for a combined DE/SE dual-phase protocol and SE triple-phase protocol were 8.9 ± 2.4 mSv (range 4.8-16.2 mSv) and 12.1 ± 3.1 mSv (range 6.4-21.1 mSv). The calculated mean dose reduction achievable by omitting the unenhanced scan was 26.7 ± 9.7% (range 10-46.1; p < 0.001).	Low
Noda, 2014	RCT	136 pts	To prospectively assess the contrast enhancement, image quality, radiation dose, and detectability of malignant pancreatic tumors with pancreatic computed tomography (CT) obtained at an 80-kilovolt (peak) (kV[p]) tube voltage setting and reduced iodine dose.	The signal-to-noise ratios in vessels were greater (P < 0.05) in the 400-80 and 500-80 groups than in the 600-120 group, and those in pancreas were comparable between the 400-80 and 600-120 groups. No significant difference was found in effective dose, image quality, lesion-to-pancreas contrast-to-noise ratio, or figure of merit between the groups. Sensitivity, specificity, and area under the receiver-operatingcharacteristic curve for detecting malignant pancreatic tumors were comparable between the groups.	High
O'Connel, 2008	Pro pilot	35 pts	The primary aim was to determine if the administration of intravenous secretin prior to contrast-enhanced computed tomography (CT) improves pancreatic enhancement and pancreatic tumor conspicuity. The second aim was to determine the optimal timing for secretin administration prior to contrast-enhanced CT.	A significant increase in pancreatic enhancement was observed when secretin was injected at 2 to 3 min before contrast material injection (the increase in pancreatic density following secretin at 2 min was 31.5+/-10 HU (29.2%) (p=.035); and at 3 min was 23.2+/-7.8 HU (22.7%) (p=.041). Pancreatic tumor conspicuity in the pancreatic phase was most marked when secretin was injected between 2 to 4 min before contrast medium, with 4 min showing a statistically significant increase in tumor conspicuity, 48.2+/-14.2 HU (p=.04).	Low
Patel, 2013	Retro	64 pts	To evaluate lesion contrast in pancreatic adenocarcinoma patients using spectral multidetector computed tomography (MDCT) analysis.	The median optimized energy level was 50 keV (range 40-77). The mean ± SD lesion contrast values (non-tumoural pancreas - tumour attenuation) were: 57 ± 29, 115 ± 70, and 146 ± 74 HU (p = 0.0005); the lengths of the tumours were: 3.6, 3.3, and 3.1 cm, respectively (p = 0.026); and the contrast to noise ratios were: 24 ± 7, 39 ± 12, and 59 ± 17 (p = 0.0005) for 70 keV, the optimized energy level, and 45 keV, respectively. For individuals, the mean ± SD contrast gain from 70 keV to the optimized energy level was 59 ± 45 HU; and the mean ± SD contrast gain from the optimized energy level to 45 keV was 31 ± 25 HU (p = 0.007).	Low
Schoellnast, 2004	Pro	41 pts	The aim of this study was to determine if a saline solution flush following low dose contrast material bolus improves parenchymal and vascular enhancement during abdominal multiple detector-row computed tomography (MDCT).	Double syringe power-injector protocol led to significantly higher parenchymal and vascular enhancement than single syringe power-injector protocol (p<0.05). The improvement in mean enhancement of the liver was 9 +/- 9 HU, of the spleen 8 +/- 10 HU, of the pancreas 7 +/- 9 HU, and of the renal cortex 8 +/- 20 HU. The improvement in mean enhancement of the portal vein was 10 +/- 17 HU of the inferior vena cava 8 +/- 13 HU and of the abdominal aorta 10 +/- 17 HU.	Low

Schueller, 2006	Pro	40 pts	To prospectively assess whether high contrast material flow rate (8 mL/sec) and individualized scan delay improve enhancement of normal pancreas with multidetector computed tomography (CT) and, as a result, tumor-to-pancreas contrast of pancreatic adenocarcinoma.	Peak contrast enhancement in pancreas was observed significantly earlier (mean +/- standard deviation, 28.7 seconds +/- 3.5 vs 48.2 seconds +/- 5.3; P < .05) and was significantly higher (129.0 HU +/- 25.7 vs 106.2 HU +/- 35.4, P < .05) with a flow rate of 8 mL/sec than with a flow rate of 4 mL/sec. Tumor-to-pancreas contrast greater than 40 HU lasted significantly longer with a flow rate of 8 mL/sec than with a flow rate of 4 mL/sec (26.4 seconds +/- 11.9 vs 8.6 seconds +/- 8.3, P < .05). With a flow rate of 8 mL/sec, an individualized scan delay of 19 seconds after aortic transit time revealed higher tumor-to-pancreas contrast than did a fixed scan delay, and tumor conspicuity was better.	Low
Schinagawa, 2003	RCT	125 pts	To evaluate the usefulness of pancreatic enhancement using a high concentration of contrast material in CT.	The peak enhancement value of the pancreas was significantly greater in group E than in groups A and B. However, no statistically significant differences were found among the other groups. group A: 100 ml, 300 mgI/mL, 3 mL/sec; group B: 2 mL/kg, 300 mgI/mL, 3 mL/sec; group C: 1.5 mL/kg, 370 mgI/mL, 3 mL/sec; group D: 2 mL/kg, 300 mgI/mL, 5 mL/sec; and group E: 1.5 mL/kg, 370 mgI/mL, 5 mL/sec.	High
Stuber, 2012	Pro	40 pts	To compare different multidetector computed tomography (MDCT) protocols to optimize pancreatic contrast enhancement.	Using an 11.1-s delay, 74.2 HU (head) were measured on average in the arterial phase and 111.2 HU (head) were measured using a 15-s delay (P < 0.0001). For the pancreatic tail, the average attenuation level was 76.73 HU (11.1 s) and 99.89 HU (15 s) respectively (P = 0.0002). HU values were also significantly higher in the portal-venous phase [pancreatic head: 70.5 HU (11.1 s) vs 84.0 HU (15 s) (P = 0.0014); pancreatic tail: 67.45 HU (11.1 s) and 77.18 HU (15 s) using Protocol 2 (P = 0.0071)].	Low
Tang, 2014	RCT	150	To assess the optimal pancreatic phase delay in terms of parenchymal enhancement and tumor-to-pancreas contrast with a bolus-tracking method.	One hundred and fifty patients were randomized to individualized scan delays of 10, 20, or 30 seconds. Pancreatic parenchymal enhancement in all patients (n = 150) was significantly higher with a delay of 20 or 30 seconds than that with 10 seconds (P < .001 for both). Tumor-to-pancreas contrast for solid tumors (n = 59) was significantly higher with a delay of 30 seconds than that with 10 seconds (P = .015). Adenocarcinoma-to-pancreas contrast during pancreatic phase was significantly higher for a 20- or 30-second delay than for a 10-second delay (P = .027 and .011, respectively) for one reader.	High
Yamamura, 2013	Pro	18 pts	To evaluate the effect of a low-tube-voltage technique and hybrid iterative reconstruction (HIR) on image quality at dynamic computed tomography (CT) of the pancreas.	The mean effective dose was significantly lower under the 100- than the 120-kV protocols (29.2 ± 3.6 vs 52.1 ± 5.1 mSv; P < 0.01). The mean contrast-to-noise ratio of the pancreatic cancer and the visual scores were significantly higher under 100 kV with HIR than those under the other 2 protocols (P < 0.01).	Low

Zamboni, 2014	Retro	60 pts	To test a single-energy low-voltage CT protocol for pancreatic adenocarcinoma.	Mean attenuation was significantly higher at 80 kV in the aorta (517.5±116.4 vs 290.3±76.4 HU) and normal pancreas (154.0±39.95 vs 90.02±19.01 HU) (all p<0.0001), while no significant difference was observed for adenocarcinoma (61.43±35.61 vs 47.45±18.95; p=n.s.). CTDI and DLP were significantly lower at 80 kV (6.00±0.90 mGy vs 10.24±2.93 mGy, and 180.4±35.49 mGy cm vs 383.8±117 mGy cm, respectively; all p<0.0001). Tumor conspicuity (HUpancreas-HUtumor) was significantly higher at 80 kV (94.2±39.3 vs 39.5±22 HU; p<0.0001). Mean image noise was significantly higher at 80kV (28.32±10.06 vs 19.7±7.1HU; p<0.0001). Effective dose was significantly lower at 80 kV (1.984±0.39 vs 5.75±1.75 mSv; p<0.0001). The total DLP for the exam was 1024±31.86 mGy cm for the 80 kV protocol and 1357±62.60 mGy cm for the 120 kV protocol (p<0.0001). Phantoms showed higher non-uniformity, slightly higher noise, slightly lower MTF (50%) and slightly higher percentage contrast for the 80 kV protocol.	Low