2D and 3D image guidance for interventional procedures

kV, mA & filtration matter, but so do advanced applications

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Disclosures

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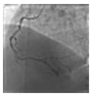
Scope

Dose reduction can be achieved through

- image acquisition techniques (kV, mA, filtration)
- image processing (denoising, edge enhancement, ..)
- 2D & 3D advanced planning & guidance

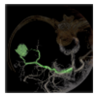
Each procedure has specific needs..

Interventional Cardiology

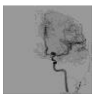


Interventional Radiology

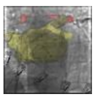
Interventional Oncology



Interventional Neuroradiology



Electrophysiology



Hybrid OR / Surgery

Specific needs in :
- Image quality
- Image processing
- Advanced planning & guidance

Each step of each procedure deserves optimal imaging

Diagnostic → Planning → Guidance → Assessment → Monitoring

2D guidance

- Fluoroscopy
- DSA
- Single shot

- Subtracted fluoroscopy
- Fluoroscopy roadmap
- DSA roadmap

- Bolus chasing

- Vascular flow imaging

- Stent visualization enhancement

3D guidance

- Cone Beam CT (CBCT)
- CBCT - CT/MR/PET/Ultrasound fusion

- Planning : trajectory planning / vessels path detection

- Guidance - 3D/2D roadmap:
  Needle guidance / vessels roadmap (ablation, CTO, embos, ..)

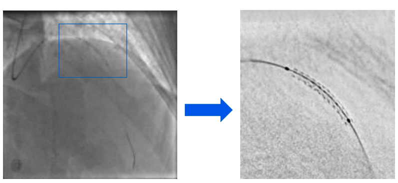
- Assessment
  - Needle stereotaxic assessment
  - Stent 3D visualization

2D advanced applications examples

Advanced 2D roadmap

Stent visualization

(GE: *StentViz & StentVesselViz* ©, Philips: *Stent Boost* ©, Siemens: *Clear Stent* ©)

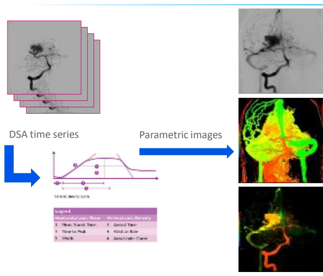


Bolus Chasing

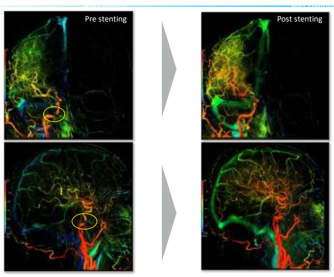
- Clinical objective: assess lower limbs vessels patency with only one contrast injection
- Application: follow a single contrast injection and paste images together
  to visualize the entire vessels

Vascular flow imaging

(GE: *AngioViz* ©, Philips: *2D Perfusion* ©, Siemens: *Syngo iFlow* ©)



Stenting assessment using AngioViz



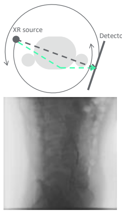
3D advanced applications

- Cone Beam CT (CBCT)
- 3D/2D roadmap
- Clinical examples:
  - Endovascular procedures
  - Needle procedures

CBCT

(GE: Innova CTHD ©, Philips: XperCT ©, Siemens: DynaCT ©)

Spin Acquisition



3D Recon
CT-like slices

3D Display

- Usually 200° (-100 to +100)
- System positioned at 0° or 90°
- Anatomy needs to be centered

CBCT proven clinical value vs DSA

- *Iwazawa et al. – 2009 – "Identifying Feeding Arteries During TACE of Hepatic Tumors: Comparison of C-Arm CT and Digital Subtraction Angiography"*
  Examined 58 possible feeding arteries in 33 patients [..]. The sensitivity, specificity, and accuracy of CBCT (96.9%, 97.0%, and 96.9%, respectively) are significantly higher than those for DSA (77.2%, 73.0%, and 75.4%). **CBCT is superior to DSA for identifying tumor-feeding arteries** during superselective TACE for HCC.
- *Mao Qiang Wang et Al. – 2016 – "Benign Prostatic Hyperplasia: Cone-Beam CT in Conjunction with DSA for Identifying Prostatic Arterial Anatomy"*
  The numbers of prostatic artery origins and anastomoses that could be identified were significantly higher with CBCT (94.7% and 97.0%) than with DSA (74.5% and 58.2%, $P < .05$). **Cone-beam CT provided essential information that was not available with DSA in 90 of 148 (60.8%) patients.**
- *Jan B. Hinrichs et Al. – 2015 - "Comparison of C-arm Computed Tomography and Digital Subtraction Angiography in Patients with Chronic Thromboembolic Pulmonary Hypertension"*
  Purpose: assess the pulmonary arteries diagnostic performance of CBCT compared to DSA in patients suffering from chronic thromboembolic pulmonary hypertension.
  Conclusion: "**CBCT** combines 3D cross-sectional imaging with an outstanding spatial resolution that allows evaluation of the pulmonary arteries from the main artery to a sub-segmental level, **revealing findings missed on DSA**.

CBCT provides clinical information DSA cannot provide One CBCT can avoid several DSAs

CBCT: It's not only about the dose…

Most Common Improvement Opportunities

Set up:

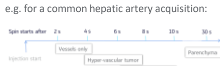
- Remove objects that may cause artifacts: cables, …
- Center the anatomy
- Adapt the reconstruction filter

Patient:

- Patient breathing instructions
- Internal metallic structures

Injection parameters

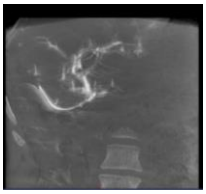
e.g. for a common hepatic artery acquisition:



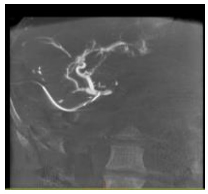
- Injection rate: from 0.5 cc/s to 5 cc/s
- Inject during full spin for vessels visualization
- Optimized delay depends on catheter position

CBCT Respiratory motion compensation

(GE only: *Motion Freeze* ©)



Breathing motion during spin

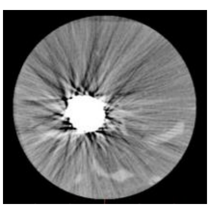


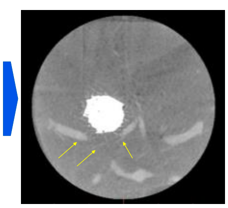
Motion compensation, avoiding redo

Avoids retakes, saves dose

Metallic Artifacts Reduction

(GE: *MAR* ©, Philips, Siemens)





Extends range of CBCT-visible anatomies

Clinical example
Hepatic radioembolization

Injection : Common hepatic artery

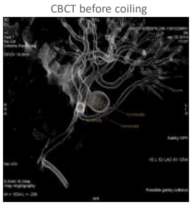
Main objective: understand the anatomy, tumor(s) location, best injection point, risk for extrahepatic perfusion

Injection : Segment 4

Main objectives: Understand tumor supply (will I treat the expected lesions ? can I be more selective?), extra-hepatic perfusion

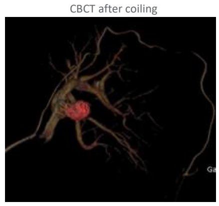
Clinical example
Renal aneurysm

CBCT before coiling



Diagnostic: measurements, shape, etc.

CBCT after coiling

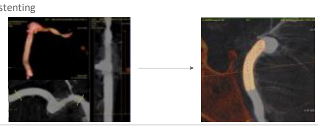


Assessment : coil position, remaining aneurysm filling, etc.

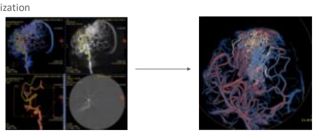
Intraprocedural 3D planning & assessment

Clinical example
Neuro advanced 3D planning & assessment

Aneurysm stenting



AVM embolization



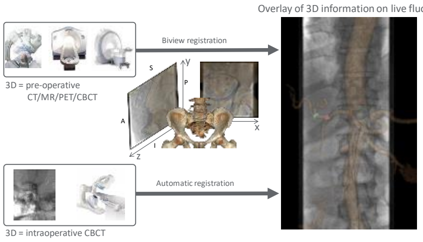
(Vessel Assist, GE)

3D advanced applications

- ✔ - Cone Beam CT
- ➡ - 3D/2D roadmap
- - Clinical examples:
  - Endovascular procedures
  - Needle procedures

3D Roadmap techniques

(GE: *Innova Vision2 ©*, Philips: *XperGuide ©*, Siemens: *Syngo iPilot ©*)

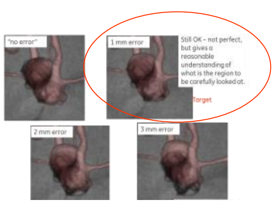


User needs:
- Ease of use
- Accuracy

Saves:
- X-ray radiation
- Iodine injection

Leveraging any 3D image to ease 2D guidance, reduce dose & contrast

Accuracy matters



Accuracy needs depends on clinical application:
- Liver procedures
- Neuro-radiology
- Cardiac

Safety feature to show live misregistration (patient motion, ..) & provide table side capability to manually adjust the registration when needed

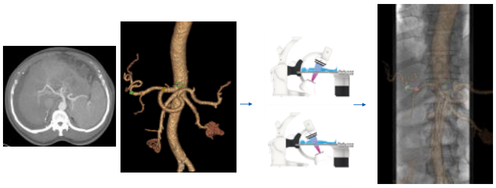
3D advanced applications

- ✓ - Cone Beam CT
- ✓ - 3D/2D roadmap
- - Clinical examples:
  - ➡ Endovascular procedures
  - Needle procedures

CT/MR guidance for complex catheterizations

- Clinical examples:
➡ Endovascular procedures
Needle procedures

(GE: ***Vessel ASSIST ©***, Philips, Siemens)



Step 1:
Arterial tree automatic segmentation
from pre-operative CT

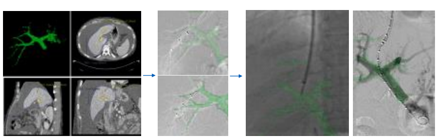
Step 2:
Fluoro / CT registration
using two views only - No spin
Bones and/or contrast small injection

Step 3:
3D live guidance under fluoro,
automatic registration with table and
gantry motion, dynamic adjustment

TIPS guidance

- Clinical examples:
➡ Endovascular procedures
Needle procedures

(GE: ***Liver ASSIST ©***)



Step 1:
Automatic liver, portal and
hepatic system segmentation
from pre-operative CT

Step 2:
Fluoro / CT registration using
two views only
No spin
Bones and/or CO2 injection

Step 3:
3D live guidance under fluoro,
automatic registration with table
and gantry motion, dynamic
adjustment

CBCT guidance for complex catheterizations

- Clinical examples:
➡ Endovascular procedures
Needle procedures

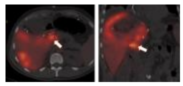
(GE: ***Vessel ASSIST ©***, Philips, Siemens)

Use of fusion with CBCT for complex case

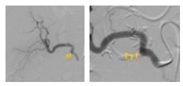
Multimodality fusion

- Clinical examples:
  - ➡ Endovascular procedures
  - Needle procedures

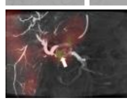
- Procedure objective: embolize the vessel responsible for the extra-hepatic enhancement seen on pre-op SPECT-CT before Y90 treatment



- Vessel suspected on DSA for the extra-hepatic enhancement



- CBCT fused with the SPECT imaging to confirm the diagnosis



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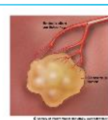
Liver transarterial embolization

- Clinical examples:
  - ➡ Endovascular procedures
  - Needle procedures



- **TACE procedure principle:**
  Embolic agent to suppress arterial blood supply
  Drug to kill the tumor cells
- Patients with primary liver cancer often have a poor liver function

  → important to be super selective during the drug delivery
- **CBCT offers:**
  Superior 3D visualization of the vasculature with a single injection
  Better tumor feeders sensitivity & visibility of extra-hepatic perfusion
  Reduced need for DSA runs
  Assessment of post-embolization contrast retention
- **But image analysis takes time…**

Need for an easy to use & automated tool, to improve transcatheter liver interventions and gain time

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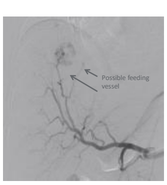
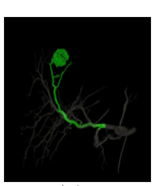
Liver transarterial embolization

(**GE: *Liver ASSIST ©***, Siemens: *Embo Guidance ©*, Philips: *EmboGuide ©*)

- Clinical examples:
  - ➡ Endovascular procedures
  - Needle procedures





planning

guidance

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Liver embolization guidance - clinical value

- Clinical examples:
➡ Endovascular procedures
Needle procedures

Iwazawa et Al. – 2013
« Comparison of the Number of Image Acquisitions and Procedural Time Required for Transarterial Chemoembolization of Hepatocellular Carcinoma with and without Tumor-Feeder Detection Software »

"Use of CBCT with automated feeder-vessel detection software in TACE of HCC helped to **reduce the number of total image acquisitions and the overall procedural time** while maintaining a comparable treatment efficacy, as compared to that of TACE without software assistance"

Cornelis et Al. – 2018
« Hepatic Arterial Embolization Using Cone Beam CT with Tumor Feeding Vessel Detection Software: Impact on Hepatocellular Carcinoma Response »

"**A higher rate of CR** was observed for HAE using Liver ASSIST guidance versus 2D imaging alone (68.4% vs. 36% $p = 0.03$). **Median dose area product was lower** when Liver ASSIST was used (149.7 Gy.cm² vs. 227.8 Gy.cm² $p = 0.05$). Use of liver ASSIST was the only factor predictive of CR ($p = 0.04$) on univariate analysis".

Imaging	Tumor multiplicity	Number of image acquisition: TACE with software (n = 50)	TACE without software (n = 84)	P
Angiography	Single (n = 61)	3.7 ± 1.8 (2–6)	6.3 ± 1.7 (3–10)	<0.001
	Multiple (n = 73)	5.2 ± 1.9 (2–10)	7.8 ± 2.4 (4–14)	0.001
	Overall	4.6 ± 1.7 (2–10)	6.6 ± 2.1 (3–14)	<0.001
C-arm CT	Single (n = 61)	3.4 ± 1.3 (2–7)	3.4 ± 1.5 (2–8)	0.884
	Multiple (n = 73)	4.4 ± 1.4 (2–7)	4.8 ± 1.2 (2–7)	0.215
	Overall	4.1 ± 1.4 (2–7)	3.8 ± 1.4 (2–8)	0.228
Total	Single (n = 61)	7.1 ± 1.8 (5–12)	9.7 ± 3.0 (5–17)	0.001
	Multiple (n = 73)	9.6 ± 2.7 (5–16)	11.0 ± 3.2 (6–20)	0.105
	Overall	8.7 ± 2.7 (5–16)	10.4 ± 3.2 (5–20)	0.004

Tumor multiplicity	Procedural time (min): TACE with software (n = 50)	TACE without software (n = 84)	P
Single (n = 61)	88 ± 22 (44–132)	109 ± 29 (58–187)	0.003
Multiple (n = 73)	112 ± 35 (50–178)	123 ± 32 (67–228)	0.219
Overall	103 ± 33 (44–178)	116 ± 31 (58–228)	0.021

Data are expressed as mean ± standard deviation (range).

Automatic tumor feeders detection in 3D
- **Finds additional feeder(s) VS DSA, improving treatment response**
- **Increases confidence during procedure**
- **Saves procedure planning time**

Overlay of the 3D embolization plan on top of fluoro
- **Helps reduce the number of DSA runs required, i.e. dose & contrast**
- **Helps determine the optimal view, easing catheterization**

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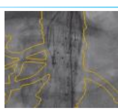
EVAR guidance

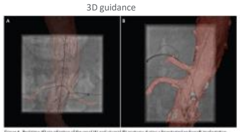
(GE: ***EVAR ASSIST ©***)

- Clinical examples:
➡ Endovascular procedures
Needle procedures

Planning on pre-op CTA/MRA:
Vessel/bone extraction
Ostium marking
Marking of planes of interest



3D guidance



S. Haulon, et al. Endovascular Today – "Using image fusion during EVAR. Experience from a high-volume aortic center shows a reduction in radiation exposure when image fusion is used. "

Assessment

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EVAR guidance - Clinical Value

(GE: ***EVAR ASSIST ©***)

- Clinical examples:
➡ Endovascular procedures
Needle procedures

Haulon, et al. - 2015
« Endovascular Today Using image fusion during EVAR. Experience from a high-volume aortic center shows a reduction in radiation exposure when image fusion is used. »

Combination of:
- Image fusion for CT roadmapping with no need for a intra-op CBCT for registration
- ALARA principle (x-ray techniques, Collimation, II distance to the patient, etc.)
- Imaging system controlled by the operator

➡ **Significant x-ray dose & contrast reduction**

Hertault, et al. - 2018
« Radiation Dose Reduction During EVAR: Results from a Prospective Multicentre Study (The REVAR Study)
By following ALARA principle in a modern hybrid room with routine use of fusion imaging, low radiation and contrast volume use were achieved compared with the published literature by all teams of a prospective multi-centre observational study. 12 times lower than the pooled mean DAP of 181 Gy.cm2 and comparable with previous single centre experience that reported a median DAP reduction from 30Gy.cm2 to 12Gy.cm2 (without any other changes in the operator practices for similar procedures).

		C-arm (n = 181)	HR (n = 96)	p
DAP (Gy·cm²)	BIF	30.0 (20.0–43.5)	12.2 (8.7–19.9)	<.01
	FEN	72.9 (52–109.2)	43.7 (24.7–57.5)	<.01
	BR	159.0 (101.8–212.4)	47.6 (37.2–108.2)	<.01
	THO	20.0 (11.4–30.0)	24.7 (22.0–28.7)	.63
Contrast medium volume (mL)	BIF	80 (65–106)	59 (50–75)	.34
	FEN	138 (100–160)	105 (70–136)	.08
	BR	226 (150–270)	120 (100–170)	<.01
	THO	100 (70–140)	80 (50–100)	.07
Intervention time (min)	BIF	95 (75–120)	92.5 (75–120)	.97
	FEN	150 (105–180)	150 (150–180)	.39
	BR	210 (150–260)	205 (169–240)	.87
	THO	117 (60–138)	80 (60–105)	.22

	Number of patient enrolled	Median DAP (Gy cm²)	Median CAK (mGy)	Median contrast medium used (g of iodine)
Centre 1	18	20.2 (7.1–38.9)	174 (67–303)	33.8 (21–39)
Centre 2	27	10.3 (8.2–14.7)	104 (88–185)	10.2 (4.0–16.0)
Centre 3	11	16.0 (11.9–22.5)	83 (71–139)	11.5 (8.8–13.1)
Centre 4	16	28.1 (13.6–43.9)	132 (51.5–203.5)	14.4 (10.5–17.0)
Centre 5	12	14.2 (11.0–24.8)	83 (62–117.1)	15 (9.6–18.8)
Centre 6	1	26.5	98	22.4

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3D advanced applications

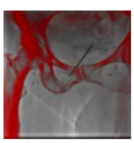
- Cone Beam CT
- 3D/2D roadmap
- Clinical examples:
  - Endovascular procedures
  - Needle procedures

Vertebroplasty

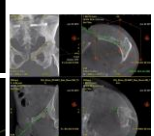
(**GE:** ***Needle ASSIST*** ©, Philips: *XperGuide* ©, Siemens: *iGuide* ©)

Clinical examples:
Endovascular procedures
Needle procedures

Procedure planning:
- Cone Beam CT acquisition
- On multi-planar image define
  The target point
  The entry point



Procedure guidance:
Export the results to the fusion software

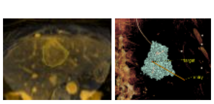


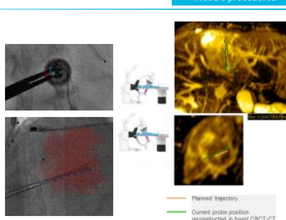
Procedure assessment

Liver tumor ablation

(**GE:** ***Needle ASSIST*** ©, Philips: *XperGuide* ©, Siemens: *iGuide* ©)

Clinical examples:
Endovascular procedures
Needle procedures





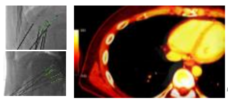
Tumor segmentation & trajectory planning on fused CBCT-MR. Guidance using the automatically generated Bulls eyes and progress views with 3D tumor from MR projected onlive fluoroscopy. Verification using Stereo3D technology.

Needle guidance clinical value

Clinical examples:
Endovascular procedures
➡ Needle procedures

Tselikas et Al. – CVIR 2015
"Percutaneous bone biopsies: comparison between flat-panel cone-beam CT and CT-scan guidance"
Conclusion:
- **Better accuracy** using Needle ASSIST guidance (3mm) (5 mm, $p=0.003$).
- **Patient & operator radiation doses lower** with Needle ASSIST vs CT ($p<.0001$).
- All biopsies technically successful
- No significant difference in puncture time nor in pathological results

Martin et Al. – RSNA 2017
"New Needle Guidance Technology in the Angiography Room: From Cone Beam CT to Stereotaxic Reconstruction From Two Fluoroscopic Views"
Conclusion:
Stereo3D (Needle ASSIST, GE) could allow verifying probes position in the 3D anatomy with a **1-2mm accuracy** while **reducing each probe guidance DAP and Air Kerma by 77% and 64% on average**, respectively



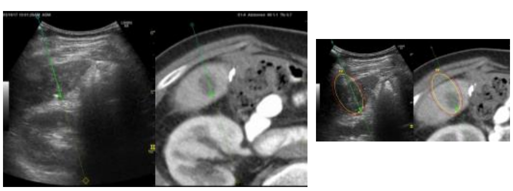
Martin et Al. – 2017

GE Proprietary 37

Multi modality fusion for liver ablation in IR

Clinical examples:
Endovascular procedures
➡ Needle procedures

(GE: Volume Navigation with INTERACT Active tracker ©, Siemens: eSieFusion ©, Philips: EpiQ Fusion ©)



Liver cryoablation guidance using fusion of preop CT on live US (Logiq E9 Ultrasound, GE) - CBCT used as a bridge for automatic preopCT-live Ultrasound fusion (INTERACT Active Tracker, GE). Needle tip is virtually tracked.

Leveraging any 3D image to allow Ultrasound guidance in IR, reducing dose & contrast

GE Proprietary 38

Multi modality fusion for liver ablation in IR

Clinical examples:
Endovascular procedures
➡ Needle procedures

(GE: Volume Navigation with INTERACT Active tracker ©, Siemens: eSieFusion ©, Philips: EpiQ Fusion ©)

Portal vein embolization guidance using fusion of preop CT on live US (Logiq E9 Ultrasound, GE) - CBCT used as a bridge for automatic preopCT-live Ultrasound fusion (INTERACT Active Tracker, GE).

Leveraging any 3D image to allow Ultrasound guidance in IR, reducing dose & contrast

GE Proprietary 39

Conclusion

Each procedure has specific needs & deserves optimal imaging

Dose reduction can be achieved through:
- image acquisition techniques
- image processing
- 2D & 3D advanced planning & guidance

2D & 3D advanced applications can help:
- better understand anatomy
- better plan treatment
- increase operator confidence
- decrease number of DSAs, dose & contrast
- ease guidance
- decrease procedure time
- improve treatment outcome

Thank you!

Any comment / question?

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