# Automated extraction of DICOM heart rate information for coronary CTA audit

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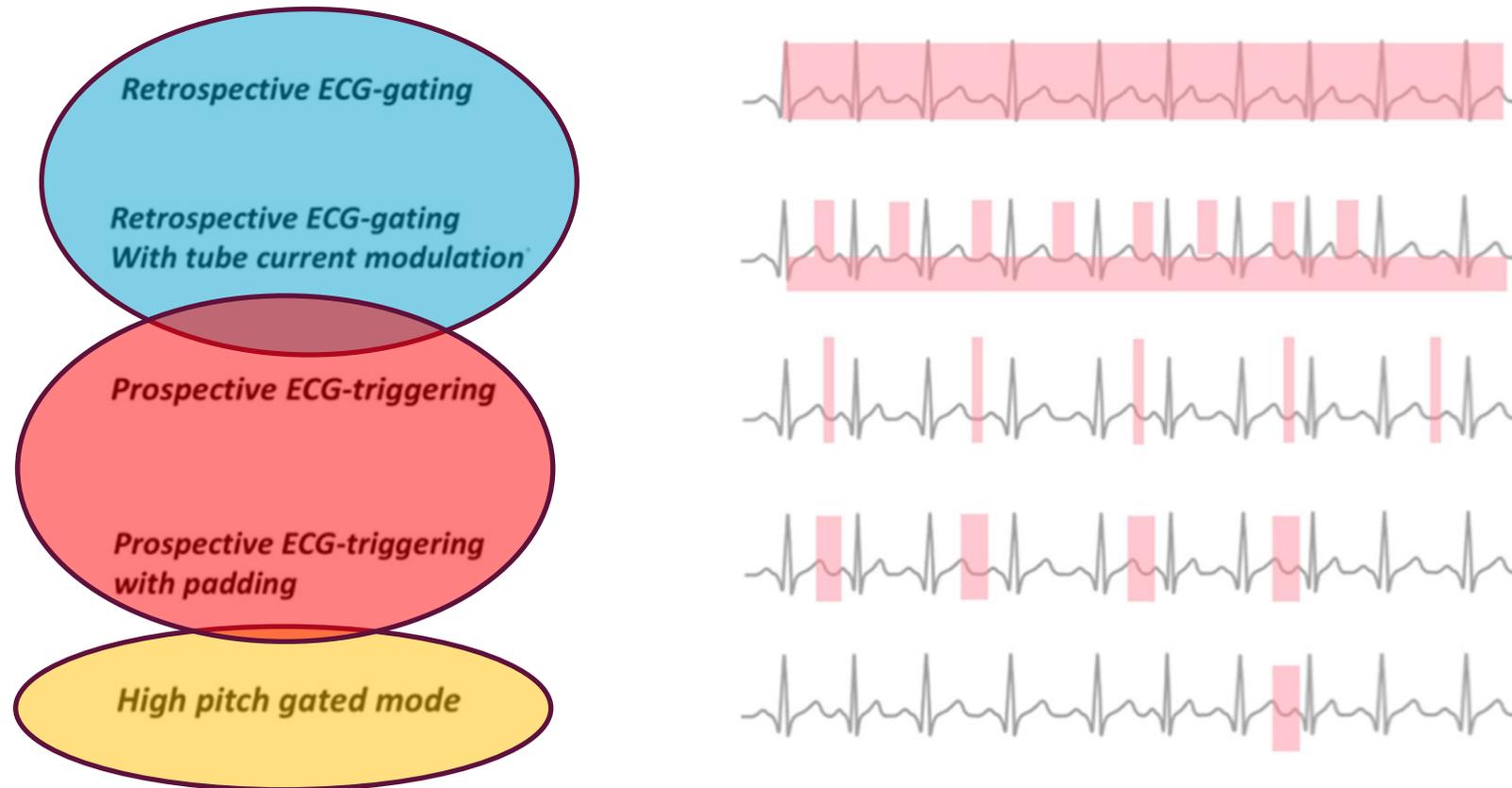
Coronary CTA

"In patients with stable chest pain referred for ICA, CCTA avoided the need for ICA in 77% of patients otherwise referred for ICA"

Healthy heart muscle

Plaque (fatty build-up)
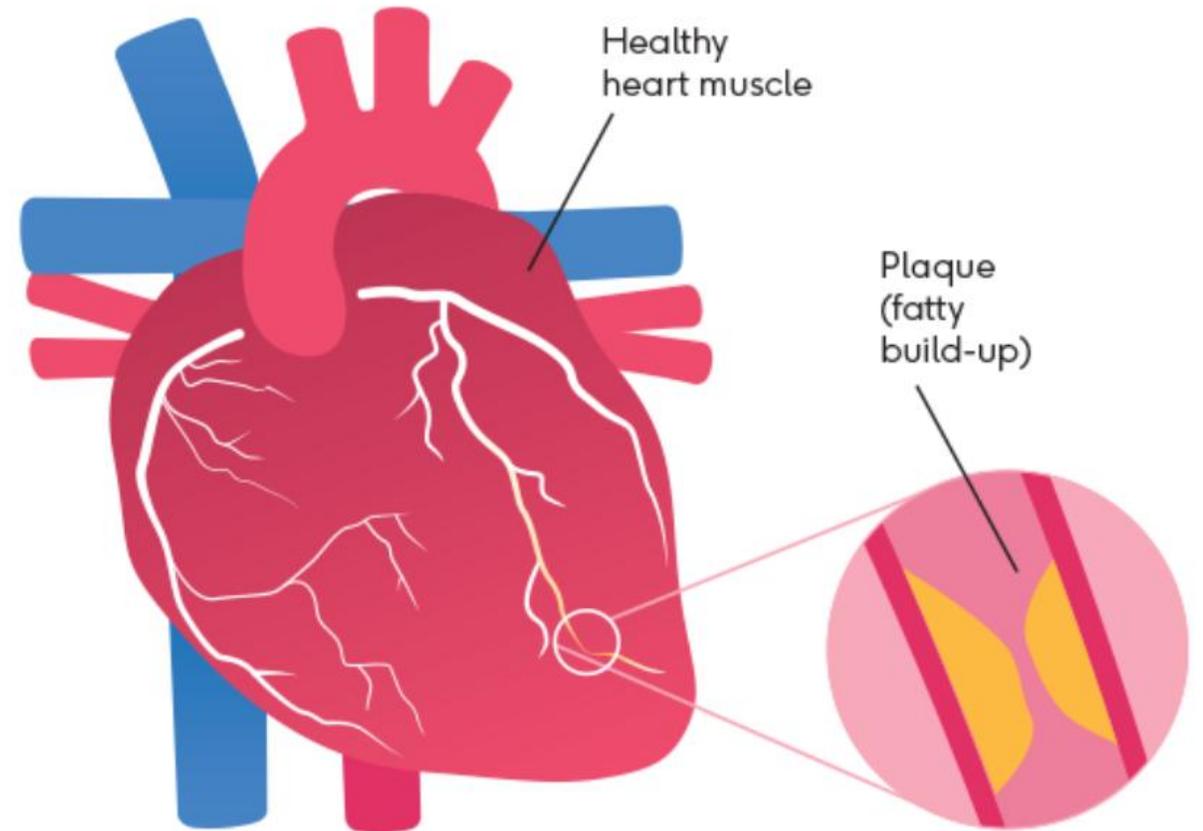
Machado, Marina F., et al. "Coronary computed tomography angiography versus invasive coronary angiography in stable chest pain: a meta-analysis of randomized controlled trials." Circulation: Cardiovascular Imaging 16.11 (2023): e015800.

https://www.bhf.org.uk/informationsupport/conditions/coronary-heart-disease
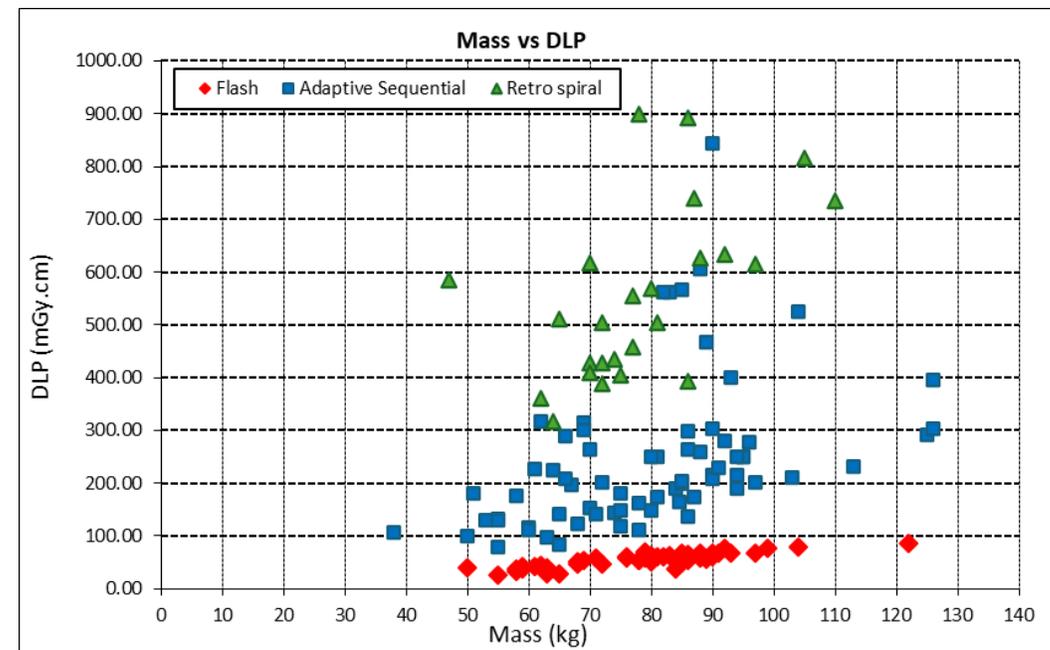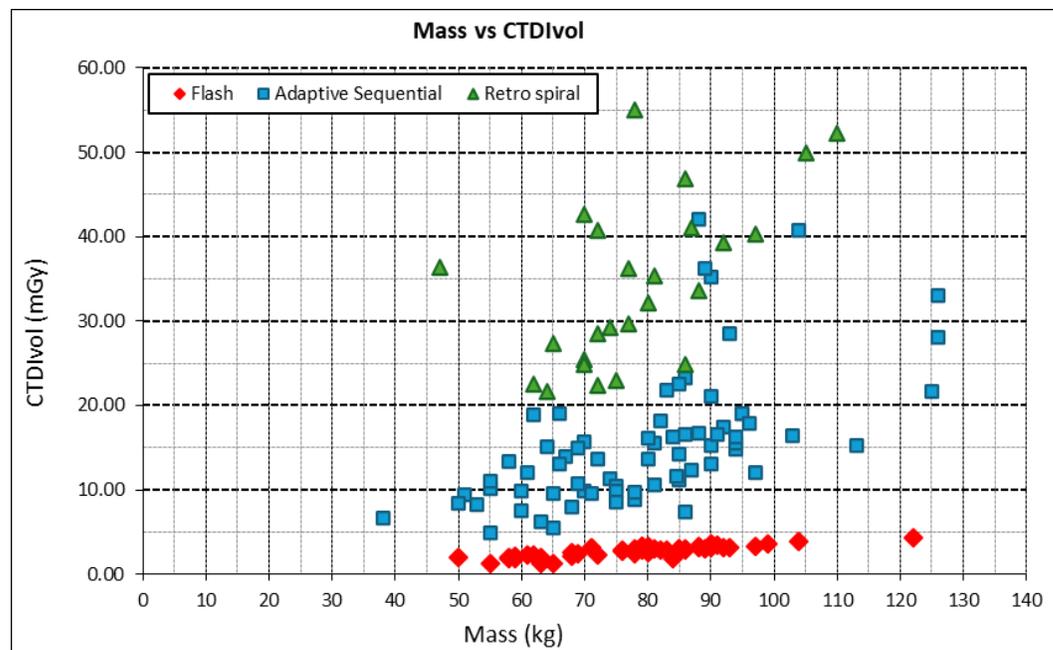
Coronary CTA

Dell'Aversana, S.; Ascione, R.; Vitale, R.A.; Cavaliere, F.; Porcaro, P.; Basile, L.; Napolitano, G.; Boccalatte, M.; Sibilio, G.; Esposito, G.; et al. CT Coronary Angiography: Technical Approach and Atherosclerotic Plaque Characterization. *J. Clin. Med.* **2023**, *12*, 7615. https://doi.org/10.3390/jcm12247615

Dosimetry

Coronary CTA – Scan selection protocol

—   Based on heart rate, heart rate variability and calcium score.

Heart rate (bpm)	Heart rate variability	Calcium score	Scan type
< 60	Low	0	Flash
60-65	Low	0-100	Diastolic gated sequential
> 65	High	0-100	Systolic gated sequential
> 60	High	> 100	UHR retrospective spiral*
< 60	Low	> 100	UHR diastolic gated sequential*

*NAETOM Alpha scanner only

— We can optimise each scan protocol but…

    — Are the correct scan types selected?

    — Are heart rates controlled (via beta blockade)?

    — Are these two factors:
        — Consistent between scanners?
        — Affected by cardiologist seniority/availability?

    — Need to know heart rate information!

Heart rate information

— Where to get heart rate information?

— Scanners generate a heart rate information series but:

    — It's an image – would require OCR to extract data.

    — Format could change between scanners and software updates, analysis would be fragile.

Heart rate information

– Search DICOM tags

– Enhanced CT images have a "Cardiac Synchronisation sequence" but our scanners don't generate enhanced DICOM information

			CIOD
▶ Enhanced CT Image			
▶ Patient		M	Module - Patient
▶ Clinical Trial Subject		U	Module - Patient
▶ General Study		M	Module - Study
▶ Patient Study		U	Module - Study
▶ Clinical Trial Study		U	Module - Study
▶ General Series		M	Module - Series
▶ CT Series		M	Module - Series
▶ Clinical Trial Series		U	Module - Series
▶ Frame of Reference		M	Module - Frame of Reference
▶ Synchronization		C	Module - Frame of Reference
▶ General Equipment		M	Module - Equipment
▶ Enhanced General Equipment		M	Module - Equipment
▶ Image Pixel		M	Module - Image
▶ Enhanced Contrast/Bolus		C	Module - Image
▼ Multi-frame Functional Groups		M	Module - Image
(0008,0023)	Content Date	1	Date
(0008,0033)	Content Time	1	Time
(0020,0013)	Instance Number	1	Integer String
(0020,0242)	SOP Instance UID of Concatenation Source	1C	Unique Identifier
(0020,9161)	Concatenation UID	1C	Unique Identifier
(0020,9162)	In-concatenation Number	1C	Unsigned Short
(0020,9163)	In-concatenation Total Number	3	Unsigned Short
(0020,9228)	Concatenation Frame Offset Number	1C	Unsigned Long
(0022,0028)	Stereo Pairs Present	3	Code String
(0028,0008)	Number of Frames	1	Integer String
(0028,6010)	Representative Frame Number	3	Unsigned Short
▼ (5200,9229)	Shared Functional Groups Sequence	1	Sequence
▶ (0008,1140)	Referenced Image Sequence	2	Sequence
▶ (0008,9124)	Derivation Image Sequence	2	Sequence
▼ (0018,9118)	Cardiac Synchronization Sequence	1	Sequence
(0018,1081)	Low R-R Value	3	Integer String
(0018,1082)	High R-R Value	3	Integer String
(0018,1083)	Intervals Acquired	3	Integer String
(0018,1084)	Intervals Rejected	3	Integer String
(0018,1088)	Heart Rate	3	Integer String
(0020,9153)	Nominal Cardiac Trigger Delay Time	1	Double
(0020,9154)	Nominal Cardiac Trigger Time Prior To R-Peak	3	Single
(0020,9155)	Actual Cardiac Trigger Time Prior To R-Peak	3	Single
(0020,9241)	Nominal Percentage of Cardiac Phase	1C	Single
(0020,9251)	R-R Interval Time Nominal	1C	Double
(0020,9252)	Actual Cardiac Trigger Delay Time	1C	Double

Heart rate information

— What do we have?

— 0018,0022 Scan Options: XOP\DSEQCARD\0001\TRGD\RSER000001\RIMA000016\TP70PC1000\OSCRATEMIN060BPM\OSCRATEMAX060BPM**OSCRATEAVG060BPM****OSCRATEVAR000BPM**\SYNCUSREDIT_NO\PITADP_AUTO\PITADPKIND_MONO\BESTPHASE_OFF\RECONTYPE_TIME\A4TP000076MS00

Heart rate information

— The HR is evaluated as a mean of all beat intervals recorded during the evaluation.

— The Variability is measured beat to beat and the mean of all variances is used (+10% to ensure there is less likely to be a variance missed – so basically 60% of the variance range)

  — Only recorded in the Scan Options DICOM tag for the Force scanner

Coronary CTA HR audit

— Write a script to interrogate PACS server and find images of interest.

— Python

— pynetdicom package

— Filter by date range, scanner, protocol and series of interest.

— Save first image of each series to a folder on dose server.

```python
# Create our Identifier (query) dataset
ds = Dataset()

ds.AccessionNumber = ""
ds.StudyDate = "20250808-20250925"
ds.StudyTime = ""
ds.StudyInstanceUID = ""
ds.QueryRetrieveLevel = "STUDY"
ds.StudyDescription = ""

StudyInstanceUID_saved = []
SeriesInstanceUID_saved = []
SOPInstanceUID_saved = []

coronary_series_descriptions = [
    "Fl_CorCTA",
    "Fl_Coronary",
    "Fl_GatedBody",
    "DS_CorAdSeq",
    "DS_SysAdSeq",
    "SS_CorAdSeq",
    "SS_SysAdSeq",
    "CorCTA",        You, 2 weeks ago • Uncommitted changes
    "CorCTA 60-80",
    "CorCTA sys",
    "Examination report",
    "Calcium Scoring",
    "CTA Coronary",
    "Gated Thoracic Aorta",

]

# Associate with peer AE at IP 172.16.181.21 and port 104
assoc = ae.associate("172.16.181.21", 104, ae_title="RT3EIPROD")

if assoc.is_established:
    # Use the C-FIND service
    for study_description in study_descriptions:

        ds.StudyDescription = study_description

        responses = assoc.send_c_find(ds, StudyRootQueryRetrieveInformationModelFind)

        for (status, identifier) in responses:
            if status.Status == 0xFF00:
                print("C-FIND query status: 0x{0:04x}".format(status.Status))
                StudyInstanceUID_saved.append(identifier.StudyInstanceUID)
                print(identifier.StudyDescription)

            else:
                print(
                    "Study: Connection timed out, was aborted or received invalid response"
                )

    # Release the association
    assoc.release()
```

Coronary CTA HR audit

— Write a script to extract heart rate
  data from DICOM header of each
  image (plus study date and
  accession number).

  — Python

  — pydicom package

— Save data to csv.

— Merge data with OpenREM dose data
  export using accession number.

```python
start = time.time()

dir_path = os.path.dirname(os.path.realpath(__file__))
cardiac_data_list = []
flow_data_list = []

cardiac_data_headings = ["Study date", "Unit", "Institution Name", "Accession number", "Patient Weight",
"PULSTART", "PULSEND", "Pulse type", "OSCRATEMIN", "OSCRATEMAX",
"OSCRATEAVG", "OSCRATEVAR", "Series name", "Series Description"]

flow_data_headings = ["Study date", "Unit", "Institution Name", "Accession number", "Patient Weight", "O

print("num entries = ", os.listdir(dir_path))

for filename in os.listdir(dir_path):

    try:
        ds = dcmread(filename, stop_before_pixels=True)
    except errors.InvalidDicomError:
        print(str(filename) + "couldn't be parsed.")
        continue

    if not "SeriesDescription" in ds:
        continue

    scan_type = (ds.SeriesDescription.split(" ")[0])

    scanners = ["NAEOTOM Alpha", "SOMATOM Force", "SOMATOM Definition Flash", "Biograph128"]

    # If the image has a scan options tag (it seems some recons might not)

    if "ScanOptions" in ds and ds.ManufacturerModelName in scanners and scan_type != "TestBolus":

        cardiac_data = ds.ScanOptions[:7]

        ms_or_pc = ds.ScanOptions[2][13:]


        if ms_or_pc == "BPM":
            cardiac_data.insert(1,"")
            cardiac_data.insert(1,"")
            cardiac_data.insert(1,"")
            cardiac_data = cardiac_data[:8]
        else:
            cardiac_data.insert(3, ms_or_pc)

        cardiac_data.append(scan_type)
        cardiac_data.append(ds.SeriesDescription)

        if "PatientWeight" in ds:
            cardiac_data.insert(0, ds.PatientWeight)
        else:
            cardiac_data.insert(0, "")
```
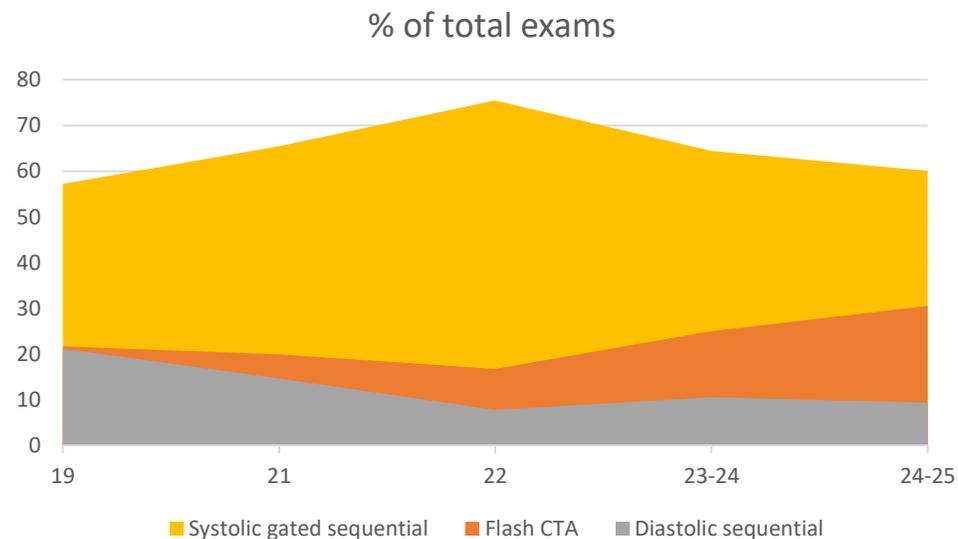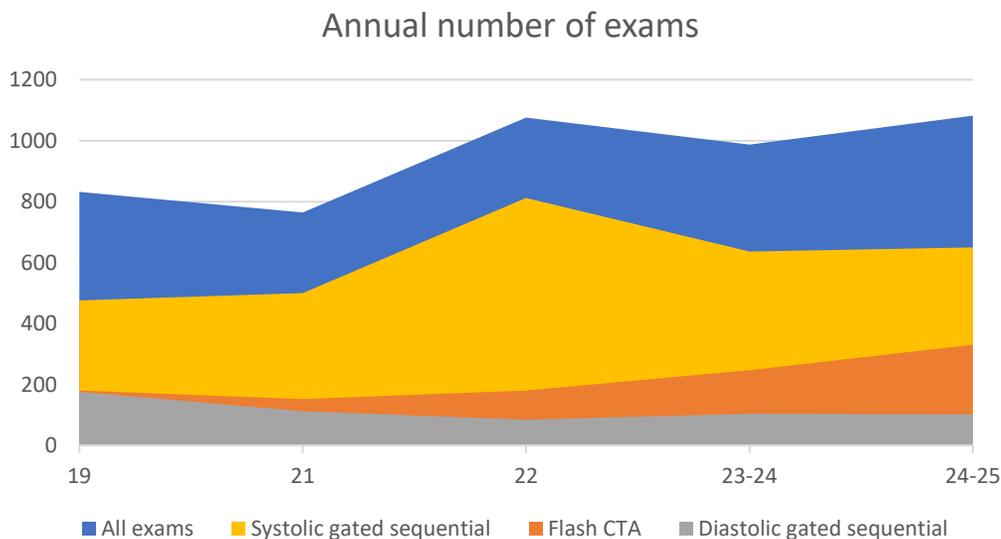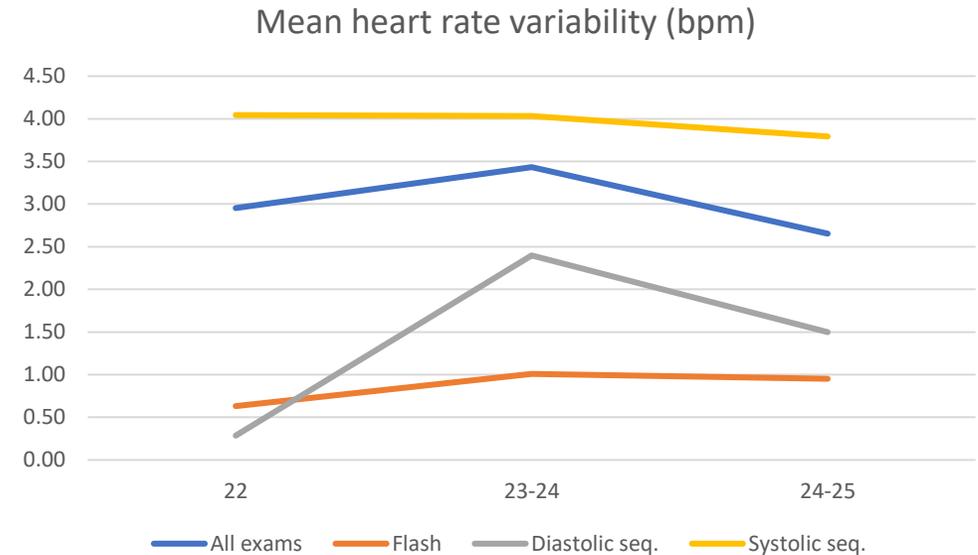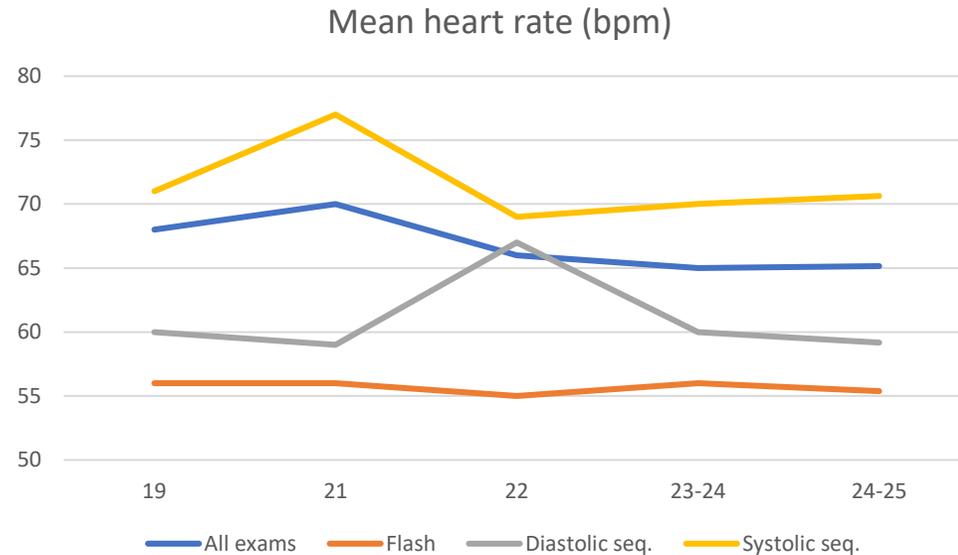
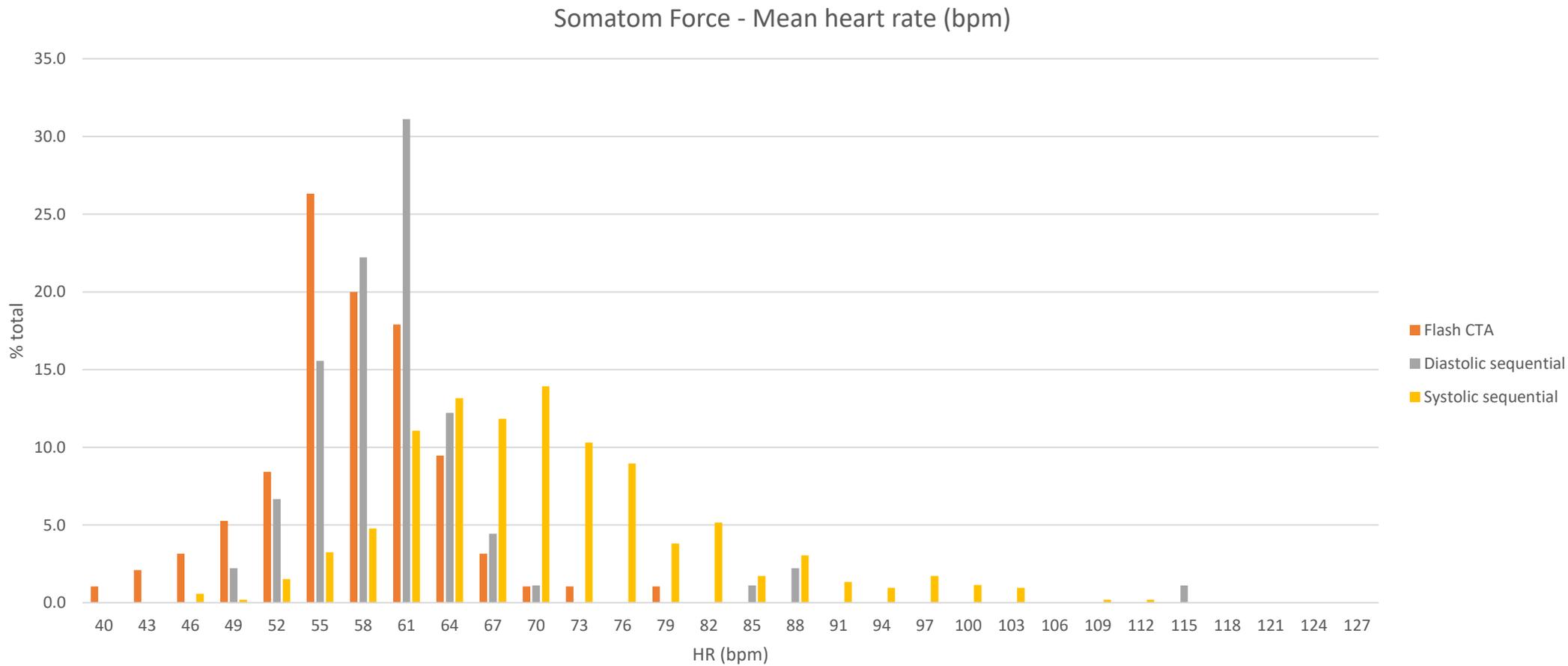# Results – main site, scan types

— Analysis of Mar-24 to Oct-25, Mar-23 to Mar-24 and 3-month periods in 2019, 2021 and 2022.

Results – main site, heart rate

— Analysis of Mar-24 to Oct-25, Mar-23 to Mar-24 and 3-month periods in 2019, 2021 and 2022.

Mean heart rate (bpm)

Mean heart rate variability (bpm)

Results – main site, HR histogram

Somatom Force - Mean heart rate (bpm)

Results – Mar 24-Oct 25

	Annual number of exams	Flash CTA median CTDIvol (mGy)	Flash CTA mean HR (bpm)	Diast. Seq. CTA median CTDIvol (mGy)	Diast. Seq. CTA mean HR (bpm)	Sys. Seq. CTA median CTDIvol (mGy)	Sys. Seq. CTA mean HR (bpm)
Flash	160	3.1	57	21.1	61	16.3	74
Force	922	1.8	55	12.8	59	12.0	70
Alpha	504	2.7	57	13.1	65	16.3	72

Results – HR by weekday, Flash CTA

Day of the week	Flash		Force		Alpha	
	Count	Mean HR	Count	Mean HR	Count	Mean HR
Sunday	0		0		0	
Monday	5	54.0	59	55.0	16	61.1
Tuesday	8	54.3	89	55.1	12	56.6
Wednesday	6	58.0	103	55.2	37	57.6
Thursday	17	58.8	115	55.0	16	55.3
Friday	9	58.6	75	55.7	21	56.2
Saturday	1	62.0	43	55.2	0	

Results – HR by weekday, Diastolic sequential

Day of the week	Flash		Force		Alpha	
	Count	Mean HR	Count	Mean HR	Count	Mean HR
Sunday	2	58.5	1	57.0	0	
Monday	2	64.5	25	60.2	10	66.8
Tuesday	9	55.0	24	58.3	6	64.7
Wednesday	3	70.7	25	57.1	28	64.5
Thursday	9	62.8	34	58.9	15	65.1
Friday	2	67.5	24	59.6	21	64.1
Saturday			3	56.7	1	

Results – HR by weekday, Systolic sequential

Day of the week	Flash		Force		Alpha	
	Count	Mean HR	Count	Mean HR	Count	Mean HR
Sunday	6	80.2	1	61.0	0	
Monday	18	62.9	144	69.5	7	73.3
Tuesday	30	69.7	162	69.6	2	74.5
Wednesday	28	80.8	154	70.1	16	70.2
Thursday	57	73.9	191	70.0	9	68.6
Friday	32	72.6	157	70.4	9	75.3
Saturday	12	85.9	51	70.2	0	

Results – UHR spiral v sequential

– NAEOTOM Alpha UHR mode is limited to a 19.2 mm maximum collimation in cardiac mode when spectral recons are required.

– Retrospective low-pitch spiral mode avoids cardiac phase discontinuities between steps but is much higher dose – particularly for low HRs where padding is increased.

– Moving towards using sequential for low stable heart rates.

	Annual number of exams	Mean HR (bpm)	Median CTDIvol (mGy)	Median DLP (mGy)
UHR seq.	65	67	16.6	258
UHR spiral	67	59	36.3	572

Limitations

— Only developed for a subset of Siemens scanners

— No HRV on older (and newer) models

— Some missing data, to be investigated

— Still potentially vulnerable to software changes

Future work

— Improve useability of scripts to allow regular audit

— Investigate remaining issues

— Audit additional relevant data e.g calcium score

— Keep an eye out for new heart rate information in DICOM tags!

— Discuss findings with clinical teams:

— Why are Flash scanner diastolic sequential CTDIvols higher than others?

— Some variation in heart rates for systolic sequential scans on the Flash scanner – why?

— Force scanner diastolic sequential heart rates consistently low, potential to increase use of Flash CTA scans?

Thanks to the RMH DR Physics Team: