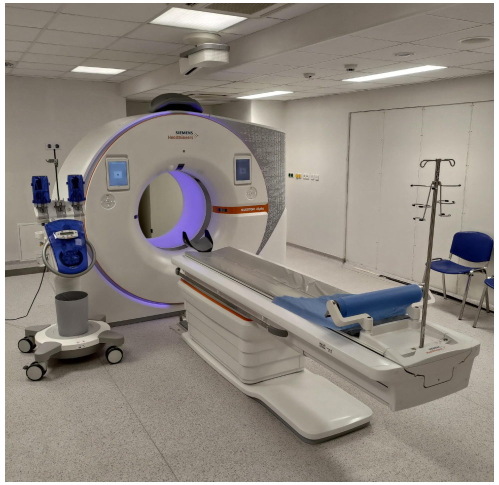
Mass General Brigham

CT-based opportunistic screening in medical imaging

November, 2024

Case vignette: Jordan wakes up with back pain



55-year old man with 12-hour history of severe, sharp left flank pain.

Bloodwork and clinical examination

Non-contrast CT in ER confirms presence of a 5mm kidney stone

Provided with pain relief, IV fluids, discharged and is scheduled for follow-up with urology

Case vignette: Jordan wakes up with back pain

12-hour history of severe, sharp left flank pain.

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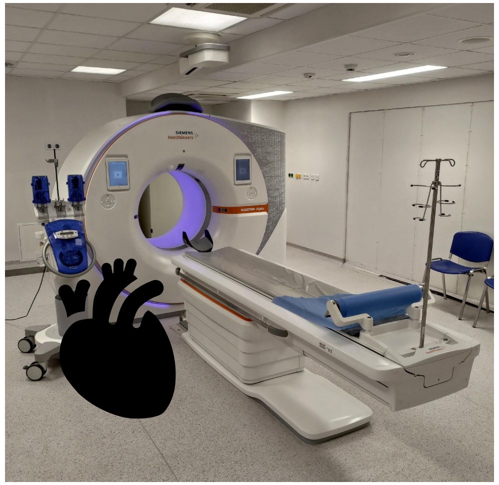
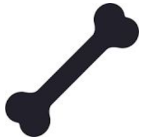


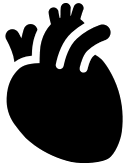
Non-contrast CT in ED confirms presence of a 5mm kidney stone

Provided with pain relief, IV fluids, discharged and is scheduled for follow-up with urology

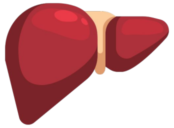
Detect osteoporosis



Estimate long-term cardiovascular risk



Detect fatty liver disease



This is reality, not science fiction

Annals of Internal Medicine®

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Original Research | 16 April 2013

Opportunistic Screening for Osteoporosis Using Abdominal Computed Tomography Scans Obtained for Other Indications

Authors: Perry J. Pickhardt, MD, B. Dustin Pooler, MD, Travis Lauder, BS, Alejandro Muñoz del Rio, PhD, Richard J. Bruce, MD, and Neil Binkley, MD | AUTHOR, ARTICLE, & DISCLOSURE INFORMATION

Radiology

REVIEWS AND COMMENTARY

Value-added Opportunistic CT Screening: State of the Art

Perry J. Pickhardt, MD

From the Department of Radiology, The University of Wisconsin School of Medicine and Public Health, E3/311 Clinical Science Center, 600 Highland Ave, Madison, WI 53792-3252. Received June 21, 2021; revision requested August 3; revision received August 24; accepted August 27. **Address correspondence to** the author (e-mail: *ppickhardt2@uwhealth.org*).

Current Osteoporosis Reports (2023) 21:65–76
https://doi.org/10.1007/s11914-022-00764-5

IMAGING (H ISAKSSON AND S BOYD, SECTION EDITORS)

Techniques for Analysis of CT Scans

[1,2] Stefan Bartenschlager[1,2]

Home › Clinical Reviews in Bone and Mineral Metabolism › Article

Opportunistic Screening for Osteoporosis Using Body CT Scans Obtained for Other Indications: the UW Experience

Review Paper | Published: 04 August 2017

Volume 15, pages 128–137, (2017) Cite this article

Home › Abdominal Radiology › Article

AI-based opportunistic CT screening of incidental cardiovascular disease, osteoporosis, and sarcopenia: cost-effectiveness analysis

Practice | Published: 20 January 2023

Volume 48, pages 1181–1198, (2023) Cite this article

Perry J. Pickhardt, Loredana Correale & Cesare Hassan

Quantifiable biomarkers and their clinical applications

Biomarker	Clinical application
Low bone density	Detect osteopenia/osteoporosis, estimate future fracture risk
Muscle density, muscle bulk	CV risk, hip fracture risk, cancer frailty, death
Visceral and subcutaneous fat (ratio, area, density)	Metabolic syndrome, diabetes, CV risk, death
Calcified atherosclerotic plaque (Agatston score)	Predict long term cardiovascular risk and death
Liver density	Detect fatty liver disease and fibrosis

Pickhardt PJ. "Value-added Opportunistic CT Screening: State of the Art." Radiology. 2022;303(2):241-254. doi: 10.1148/radiol.211561.

Some findings are immediately actionable

	Finding	Clinical scenario	Action (if model output is positive)
Vascular calcs/atherosclerotic disease	• Quantification – modified Agatston score	• Patient known to have higher cardiovascular risk	• **Start patient on statins**
		• Patient with no risk factors	• Consider referring to Cardiologist
Bone mineral density	• At L1 vertebral body, 99-136 HU is threshold (below 99 is considered osteoporosis)*	• Patient at higher risk of osteoporosis/osteopenia because of age	• **Consider DEXA** • **Consider bisphosphonates**
		• Patient known to be taking drugs that reduce BMD	• Consider DEXA
		• Patient with no risk factors	• Consider DEXA

Source: *Gausden EB, Nwachukwu BU, Schreiber JJ, Lorich DG, Lane JM. **Opportunistic Use of CT Imaging for Osteoporosis Screening and Bone Density Assessment: A Qualitative Systematic Review.** J Bone Joint Surg Am. 2017 Sep 20;99(18):1580-1590. doi: 10.2106/JBJS.16.00749. PMID: 28926388; Pickhardt PJ, Graffy PM, Perez AA, Lubner MG, Elton DC, Summers RM, Opportunistic Screening at Abdominal CT: Use of Automated Body Composition Biomarkers for Added Cardiometabolic Value. Radiographics. 2021 Mar-Apr;41(2):524-542. doi: 10.1148/rg.2021200056. PMID: 33646902; PMCID: PMC7924410.

Cost-effectiveness data being generated

Focused on **cardiovascular risk** and **low bone density**, where modelled interventions were statin and alendronate therapy

Modelling performed to compare impact of incorporating **incidental CT findings** into clinical decision-making

Significant cost savings even with accounting for costs of the AI tools

Shows **improved clinical outcomes** while reducing healthcare costs across a range of assumptions.

	Males 55 years old with 10% 10-year CV risk ($n = 10{,}000$)			Females 55 years old with 6% 10-year CV risk ($n = 10{,}000$)		
	Treat none (Natural history)	Treat all (Universal statin)	Opportunistic CT screening**	Treat none (Natural history)	Treat all (Universal statin)	Opportunistic CT screening**
55-year-old, 10-year cardiovascular risk*	9.8% (8.6–11.0%)	8.2% (7.1–9.2%)	8.1% (7.0–9.0%)	5.9% (4.8–7.0%)	4.9% (3.9–5.8%)	5.1% (4.1–6.0%)
Number eligible for statin therapy at baseline		10,000	6795 (6491–7138)		10,000	3800 (3422–4184)
Number elgible for BMD treatment at baseline			1030 (736–1276)			1080 (924–1226)
Number eligible for sarcopenia intervention			329 (101–452)			322 (99; 453)
Fatal and non-fatal cardiac events	821 (724–908)	669 (587–743)	659 (578–728)	507 (413–591)	412 (334–482)	433 (355–507)
Fatal and non-fatal strokes events	166 (138–191)	150 (125–173)	148 (123–171)	86 (63–105)	77 (57–94)	79 (58–96)
Hip fractures	47 (20–64)	48 (21–64)	42 (18–57)	97 (82–111)	98 (82–111)	86 (82–98)
Death from all cardiovascular events	98 (75–117)	82 (62–98)	80 (62–96)	52 (37–63)	43 (31–52)	45 (33–55)
Death from any cause	1062 (1027–1093)	1036 (1005–1064)	1033 (1004–1060)	574 (550–595)	562 (541–580)	[illegible]63 (542–581)
Outcomes (discounted at 3%/yr)						
Life expectancy, yrs (per person)	8.276 (8.264–8.288)	8.284 (8.274–8.295)	8.285 (8.275–8.295)	8.451 (8.443–8.459)	8.455 (8.4[illegible]–8.462)	[illegible] (8.448–[illegible]23)
QALY expectancy (w/ statin disutility), yrs (per person)	8.221 (8.202–8.243)	8.233 (8.218–8.252)	8.236 (8.221–8.254)	8.415 (8.401–8.430)	[illegible]	[illegible]

Opportunistic CT screening leads to lower cardiac events, strokes and death from all CV events, in Men

Pickhardt PJ, Correale L, Hassan C. AI-based opportunistic CT screening of incidental cardiovascular disease, osteoporosis, and sarcopenia: cost-effectiveness analysis. Abdom Radiol. 2023 Jan;48(3):1-18. doi: 10.1007/s00261-023-03800-9.

Incidental findings can be a double-edged sword, but this technology can also have huge benefits for patients

General concerns about incidental findings

Unnecessary follow-up tests: Can lead to additional imaging or invasive procedures

Patient anxiety: Discovering unexpected abnormalities can cause significant stress and worry

Overdiagnosis and false positives: May lead to the identification of harmless conditions

Increased healthcare burden: Managing incidental findings can strain healthcare resources, diverting attention from more urgent or critical cases.

Initial data shows cost effectiveness and improved clinical outcomes

Possible huge net benefit to patients

Barriers to adoption

Clinician factors

- Follow-up responsibility
- Concerns about costs to patients
- Need for larger body of evidence
- Trustworthiness of AI

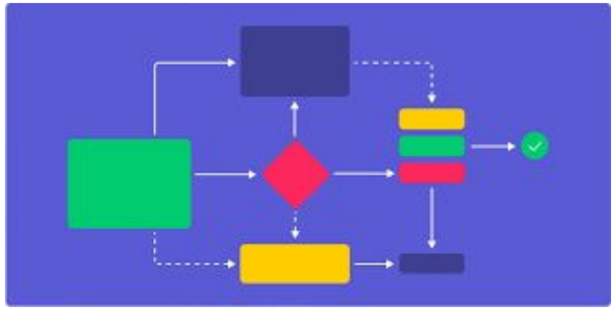
Focus here

Patient factors

- Consent
- Communications

Financial factors

- Lack of reimbursement path
- Lack of data showing measurable quality improvement



Workflow factors

- Lack of fully integrated product

Research: PCP perspectives on the value of opportunistic screening

ELSEVIER

Clinical Imaging

Volume 112, August 2024, 110210

Cardiothoracic Imaging

Primary care provider perspectives on the value of opportunistic CT screening

Adam E.M. Eltorai [a], Suzannah E. McKinney [b], Marcio A.B.C. Rockenbach [b], Saby Karuppiah [c], Bernardo C. Bizzo [b], Katherine P. Andriole [a b]

Research: PCP perspectives on the value of opportunistic screening

Surveyed US Internal and Family Medicine residents, n = 71

Low Familiarity with AI/OS:

- 95.8% were **unfamiliar** with opportunistic CT screening (OS), **despite 74.6% having heard of AI/machine learning.**

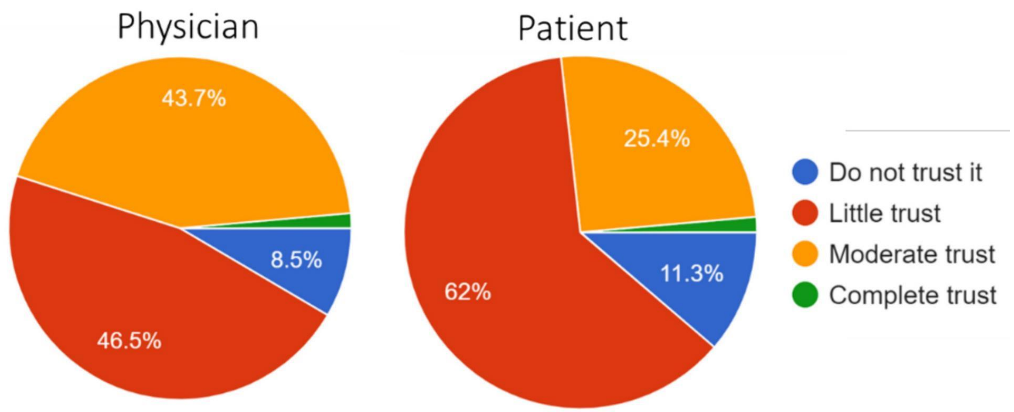
Clinical Impact:

- PCPs indicated that OS results would **likely influence management decisions,** especially for cardiovascular disease, aortic aneurysms, and liver fibrosis.

Research: PCP perspectives on the value of opportunistic screening

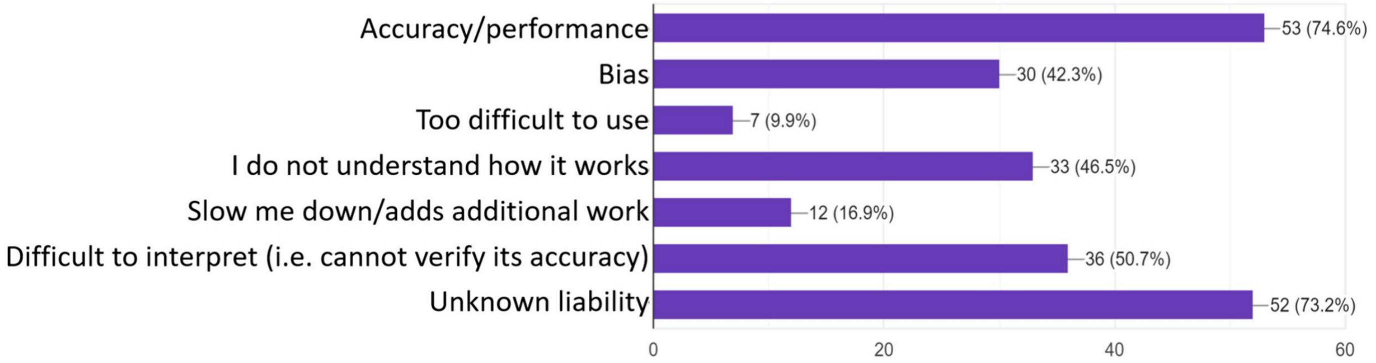
Surveyed US Internal and Family Medicine residents, n = 71

Physicians' (left) and physicians' expectations of patient (right) trust in AI/ML-generated output.



- Majority report little to no trust

Clinician concerns related to using AI/ML in clinical practice



- Accuracy and performance, and unknown liability are largest concerns

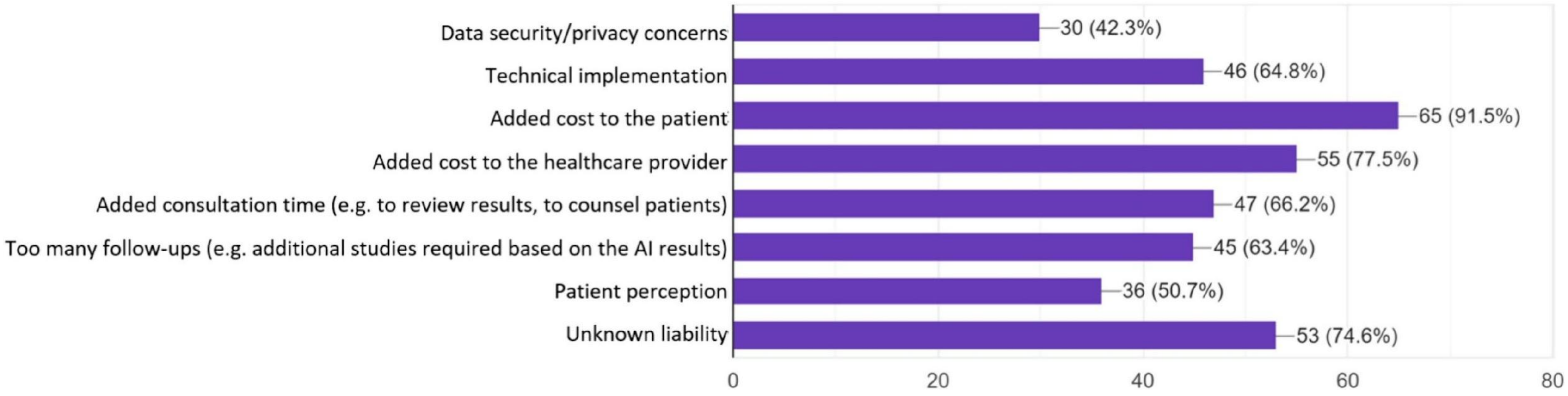
Research: PCP perspectives on the value of opportunistic screening

Surveyed US Internal and Family Medicine residents, n = 71

Financial decision-making

- 70.5% believed PCP practices are unlikely to pay for OS

PCP concerns about opportunistic CT screening tool deployment.



19 clinician user interviews conducted, 44% of clinicians are supporters of model*

	Specialty	Type of practice	Supporter
1	Cardiologist	AMC	Supporter
2	Cardiologist	AMC	Neutral
3	Cardiology/Radiology	AMC	Neutral
4	Cardiothoracic surgeon	Community	Neutral
5	Endocrinologist	AMC	Supporter
6	General Surgeon	Community	Not supporter
7	Internist	Community	Not supporter
8	Lead CT tech	Community	Neutral
9	Oncologist	AMC	Supporter
10	Oncologist	AMC	Neutral
11	Oncologist	AMC	Neutral
12	Oncologist	AMC	Not supporter
13	Abdominal Radiologist	AMC	Neutral
14	Neuroradiologist	AMC	Not supporter
15	Radiologist	AMC	Supporter
16	Radiologist	AMC	Supporter
17	Radiologist	Community	Supporter
18	Radiologist	Community	Neutral
19	Transplant nephrologist	AMC	Supporter

*Think tool would be interesting, generally supportive of work

Supporter Neutral Not supporter

Many clinicians are unwilling to pay despite being supporters of the work

	Specialty	Type of practice	Willing to pay?
1	Cardiologist	AMC	Unsure
2	Cardiologist	AMC	Unsure
3	Cardiology/Radiology	AMC	No
4	Cardiothoracic surgeon	Community	Unsure
5	Endocrinologist	AMC	Unsure
6	General Surgeon	Community	No
7	Internist	Community	No
8	Lead CT tech	Community	Unsure
9	Oncologist	AMC	No
10	Oncologist	AMC	No
11	Oncologist	AMC	No
12	Oncologist	AMC	Unsure
13	Abdominal Radiologist	AMC	Unsure
14	Neuroradiologist	AMC	No
15	Radiologist	AMC	Unsure
16	Radiologist	AMC	Unsure
17	Radiologist	Community	Unsure
18	Radiologist	Community	No
19	Transplant nephrologist	AMC	Clear yes

Most promising areas (rows 13–19)

*Think tool would be interesting, generally supportive of work

Clear yes | Unsure | No

Themes from non-supporter respondents

	Theme	Quotes
1	**Lack of budget for anything without a direct ROI**	*“We don’t even have budget to print info sheets for patients”*
2	**Believe in theoretical value, but need large body of clinical evidence + reimbursement code to change practice**	*“Do I want this info on my patients now, before there are trials done to show me what to do with it? No. I would not.”*
3	**Reluctance to further increase burden of incidental findings, without clear value**	*“It is very overwhelming for us; we have to do so much to prove it is just incidental”* *“The most annoying thing to us, is incidentals; people are not going to be jumping to add more incidentals to their report.*
4	**Unclear processes for assessing and onboarding AI tools**	*"The way the healthcare system is setup makes it difficult to add this type of product to the workflow"*

Next steps:

1) **Data**
   1) Evidence generation on clinical outcomes, cost effectiveness and quality improvement

2) **Education**
   1) Education and training for medical professionals about AI

3) **Improvements in AI governance**
   1) Improve clarity in processes for assessing and onboarding AI tools

To drive adoption of AI in medicine, we need more than a model that works: We must understand how it fits into the bigger picture including people dynamics.

Bonus: MGB AI Arena just announced

Collaborative of Prominent Academic Institutions Launches Groundbreaking Healthcare AI Challenge

Nov 13, 2024

Patient Care | Artificial Intelligence | Radiology

The Healthcare AI Challenge is a first-of-its-kind interactive virtual environment that enables healthcare professionals to experience and assess the world's most advanced AI healthcare solutions.

Mass General Brigham AI is hosting the Healthcare AI Challenge, a multi-institutional virtual, interactive series of events where healthcare professionals can explore and assess the latest AI healthcare technologies in real-world healthcare scenarios.

The Healthcare AI Challenge Collaborative is launching with a diverse set of healthcare institutions and their healthcare professionals, including Mass General Brigham; Emory Healthcare; the Department of Radiology at the University of Wisconsin School of Medicine and Public Health; and the Department of Radiology at the University of Washington School of Medicine. The American College of Radiology

MGB, Emory to test AI models from Amazon, OpenAI

BROCK E.W. TURNER

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Quantifiable biomarkers and their clinical applications

	Value that can be quantified	Clinical application
Bone	Low bone density: Trabecular HU, femoral neck DXA–equivalent T-score	Detect osteoporosis, identify prevalent vertebral fractures, estimate future fracture risk
Skeletal muscle	Muscle density, muscle bulk (area or volume)	Sarcopenia, CV risk, hip fracture risk, cancer frailty, death
Fat	Visceral and subcutaneous fat (ratio, area, density)	Metabolic syndrome, diabetes, CV risk, death
Cardiovascular	Calcified atherosclerotic plaque (Agatston score)	Predict long term cardiovascular risk and death
Liver	Liver HU, volume (total or segmental), surface nodularity	Detect fatty liver disease and fibrosis

Initial evidence suggests that their ability to help radiologists assess biologic age and predict future adverse cardiometabolic events rivals even the best available clinical reference standards.

Pickhardt PJ. "Value-added Opportunistic CT Screening: State of the Art." Radiology. 2022;303(2):241-254. doi: 10.1148/radiol.211561.

Technical approach is straightforward, taking low bone density models as an example:

Architectures

Feature-Based Imaging Feature Analysis:
- Manually extracting various features and incorporating them into a training set for AI-based imaging classification

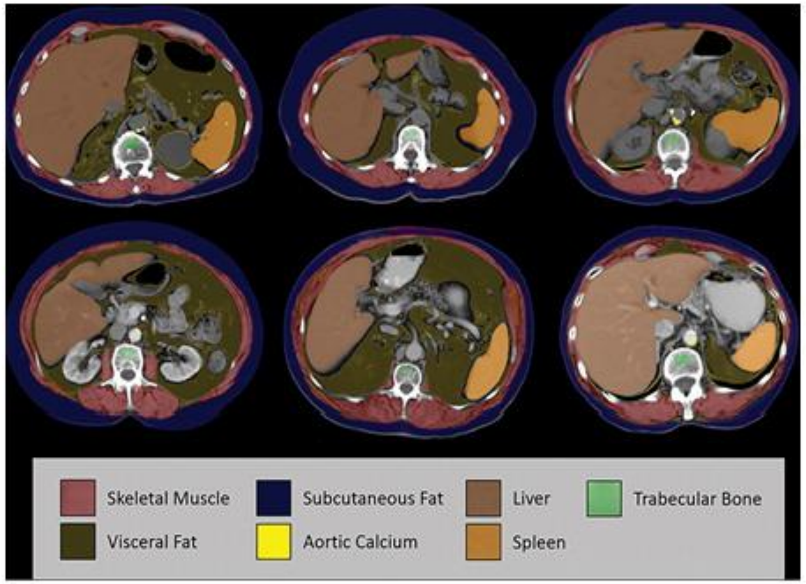
Deep Learning-Based Analysis (e.g., CNNs):
- Employ deep learning to automatically extract valuable imaging features by learning patterns directly from input images
- Enables the detection and processing of distinct diagnostic patterns and imaging features that go beyond what a human reader can accomplish, potentially improving BMD classification.

Technical challenges models help adjust for

- Beam hardening artifacts
- Patient positioning
- Hardware-related variations, including different scanner manufacturers and models
- Differences in protocols
- Lack of phantoms

Ong W, Liu RW, Makmur A, Low XZ, Sng WJ, Tan JH, Kumar N, Hallinan JTPD. Artificial Intelligence Applications for Osteoporosis Classification Using Computed Tomography. Bioengineering (Basel). 2023 Nov 27;10(12):1364. doi: 10.3390/bioengineering10121364.

Value-added Opportunistic CT Screening: State of the Art



Case examples of fully automated CT-based body composition measures from six different adult patients. Noncontrast (top row) and postcontrast (bottom row) CT images at the L1 vertebral level demonstrate AI-based segmentation.

- Abdominal and thoracic CT scans contain robust data incidental to the imaging indication that can and should be leveraged for patient benefit.
- Body composition measures and other CT biologic markers demonstrate clinical value for risk stratification and prevention.
- CT-based opportunistic screening markers can be fully automated and represent understandable AI applications.
- By demonstrating improved health outcomes, these opportunistic CT-based measures should be attractive to both payers and health care systems as value-based reimbursement models mature.
- Emerging data may prove compelling enough to justify standalone "intended" CT screening.

Pickhardt PJ. Published Online: March 15, 2022
https://doi.org/10.1148/radiol.211561

Paper methodology summary

Paper first developed a base case showing how we expect a cohort of Americans to develop disease over time

10 year total modelling timeline

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10

10K hypothetical US adults between **45-75**

- No CV disease or hip # at entry
- Assumed 10 year CV risk between 4.9 to 19.2%,
- Assumed 10-year risk of osteoporotic hip fracture from 0.2 to 4.4%

Projected changes in health status each year, based on assumptions about natural course of disease in the US

E.g., by year 4, X of the adults had developed cardiovascular disease, Y of the adults had suffered from an osteoporotic hip fracture

Interventions were modelled and compared to base case

- Paper focuses on CV risk, risk of osteoporotic hip fracture, and sarcopenia
- To be able to more easily examine the methodology with one example, **I focus on CV risk**

Two CV interventions were modelled

		Patients started on statin?	Comment
0	**Treat none**		
1	**Treat all**	10,000	• All hypothetical patients were started on a statin • Everyone was assigned to **moderate statin therapy,** which was modeled as providing a mean **35%** relative reduction in CV risk • Assumed a 55% rate of statin adherence

2	**Treat some, based on CT opportunistic screening**	6,705	• No real CTs were used in this research, as all patients were hypothetical
			• Researchers assumed that all hypothetical patients, had a CT conducted for unrelated reasons
			• Researchers assumed a baseline level of CT based AAC Agatson scores in our dataset of 10K patients, based on a **dataset of asymptomatic outpatient adults**
			• The AAC Agatston score was used to guide statin treatment for CV prevention in the opportunistic CT screening scenario: patients with scores of 1–1000 and > 1000 were advised to begin statin monotherapy
			    • Patients with AAC Agatston scores with a 1–1000 score received moderate intensity statin therapy, modeled as providing a mean **35%** relative reduction in CV risk
			    • Patients with AAC Agatston scores > 1000 were modeled for **intensive statin treatment,** receiving a **45%** relative risk reduction
			    • **Assumed a 65% mean adherence rate***

*Higher adherence rate for opportunistic screening patients, assumes that patients who can visualize moderate calcium deposits on their own CT, have a significantly higher rate of adherence to statin treatment

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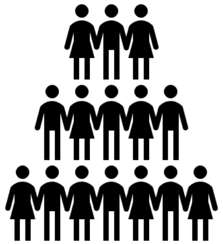
10 year total modelling timeline

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10

10K hypothetical US adults between **45-75**

Calculate health outcomes and costs every year, for three scenarios



No intervention

Everyone gets a statin

6,705/10,000 get a statin (based on opportunistic AI on abdominal CT)

Cost modelling

Costs of risk assessment and intervention

		Patients started on statin?	Cost modelling
0	**Treat none**		N/A
1	**Treat all**	10,000	• Included direct costs of the risk assessment process • For "treat all", assumed a comprehensive physical examination and laboratory fees for lipid levels ($170 per patient at the baseline visit). • Assumed an annual cost of $180 per patient for the use of statins • Did not include the cost of CT scan because we assumed it was ordered separately as part of their clinical care • Did include cost of AI software – fixed cost of $65,300 + annual cost of $21,770
2	**Treat some, based on CT opportunistic screening**	6,705	

Costs of morbidity

- Distinguished CV event-related costs from ongoing costs
  - Event-related costs contained the costs of hospitalization, diagnostic workup, (surgical) intervention, rehabilitation, and nursing home admission during the first year after an event.
  - Ongoing costs reflected the costs of the resource use in the subsequent years after an event.
- These costs were assigned to a patient for each year that the patient remained in a certain health state

Results

	Males 55 years old with 10% 10-year CV risk ($n = 10{,}000$)			Females 55 years old with 6% 10-year CV risk ($n = 10{,}000$)		
	Treat none (Natural history)	Treat all (Universal statin)	Opportunistic CT screening**	Treat none (Natural history)	Treat all (Universal statin)	Opportunistic CT screening**
55-year-old, 10-year cardiovascular risk*	9.8% (8.6–11.0%)	8.2% (7.1–9.2%)	8.1% (7.0–9.0%)	5.9% (4.8–7.0%)	4.9% (3.9–5.8%)	5.1% (4.1–6.0%)
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Fatal and non-fatal strokes events	166 (138–191)	150 (125–173)	148 (123–171)	86 (63–105)	77 (57–94)	79 (58–96)
Hip fractures	47 (20–64)	48 (21–64)	42 (18–57)	97 (82–111)	98 (82–111)	86 (82–98)
Death from all cardiovascular events	98 (75–117)	82 (62–98)	80 (62–96)	52 (37–63)	43 (31–52)	45 (33–55)
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Outcomes (discounted at 3%/yr)						
Life expectancy, yrs (per person)	8.276 (8.264–8.288)	8.284 (8.274–8.295)	8.285 (8.275–8.295)	8.451 (8.443–8.459)	8.455 (8.448–8.462)	8.454 (8.448–8.4623)
QALY expectancy (w/ statin disutility), yrs (per person)	8.221 (8.202–8.243)	8.233 (8.218–8.252)	8.236 (8.221–8.254)	8.415 (8.401–8.430)	8.419 (8.408–8.433)	8.421 (8.409–8.434)

Opportunistic CT screening leads to lower cardiac events, strokes and death from all CV events, in Men

Paper's overall conclusions: AI-based opportunistic screening approach is most cost-effective

		Patients started on statin?	For 55-year-old men aged at 10% CV risk (base case)
0	**Treat none**		• Costs related to CV events, hip fractures, or sarcopenia were estimated at $5449 per individual per year.
1	**Treat all**	10,000	• Costs related to CV events, hip fractures, or sarcopenia were estimated at $5634 per individual per year • Did not prevent enough symptomatic CV events to offset the statin costs ($957 per individual) compared with AI-assisted CT-based opportunistic screening
2	**Treat some, based on CT opportunistic screening**	6,705	• Costs related to CV events, hip fractures, or sarcopenia were estimated at $5235 per individual for year