

Prospective and Clinical Evaluation of an AI-Driven Decision Support System

William Bolton

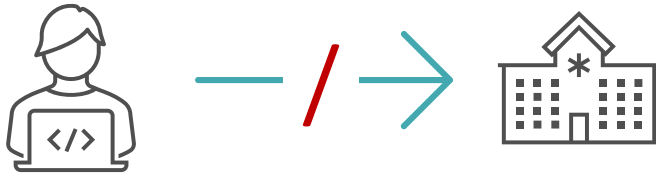
ICID

4th December 2024

The data and findings presented here are part of ongoing, unpublished work.
Please refrain from sharing or distributing this information publicly. Thank you.

I have no conflicts of interest to declare.

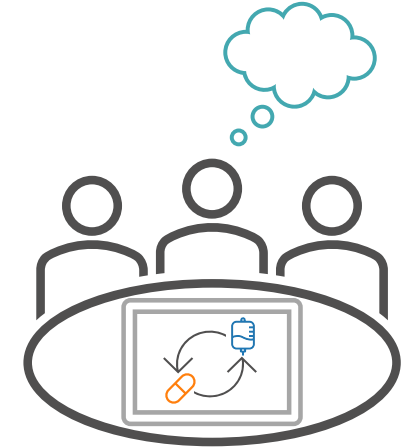
Translating AI technology for infectious disease from research into healthcare settings is difficult.



Few AI decision support systems have been truly **translated, integrated and adopted** in healthcare



Infectious disease is especially **complex** due to **behavioral**, and cultural factors as well as **uncertainty** and frequent lack of a ground truth



We conducted **clinical evaluation** of an AI system for IV-to-oral switching to understand **user perceptions** and its **impact** on decision making

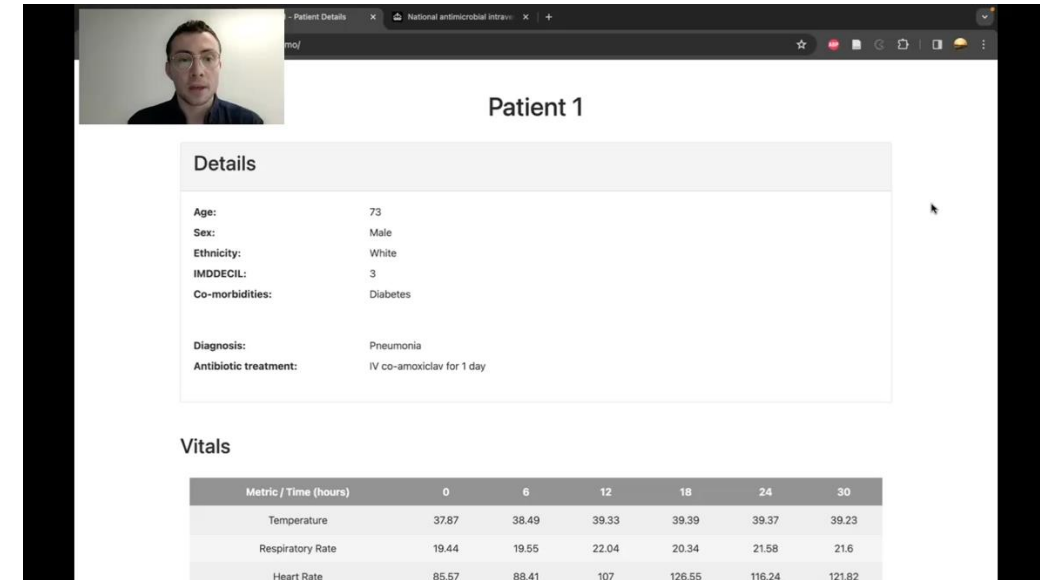
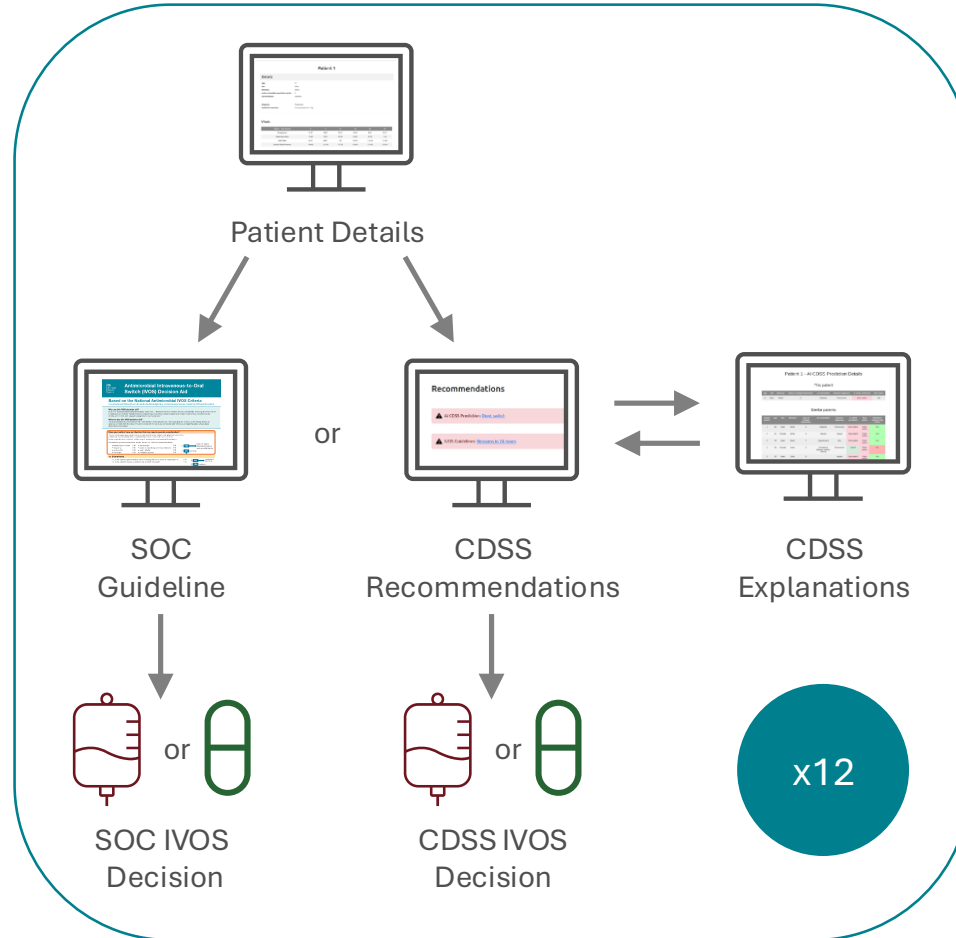
A randomized clinical vignette methodology with semi-structured interviews and questionnaires was used.

Clinicians

- Information sheet
- Informed consent
- Video demonstration

Semi-structured
Interview

SUS & TAM
Questionnaires



AI algorithms have been developed that use routinely collected data to support IV-to-oral antibiotic switching.



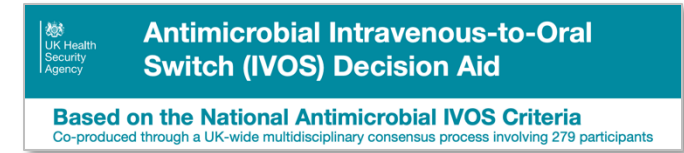
One key challenge of stewardship is **determining when to switch** antibiotics from **IV-to-oral administration**

Numerous studies have shown that **oral therapy can be non-inferior to IV**



There is a **poor understanding** of the factors that facilitate or inhibit an individual from receiving oral therapy

FEATURES



RESULTS

Dataset	AUROC Result
MIMIC	0.78 (SD 0.02)
eICU	0.72 (SD 0.02)
ICHT	0.78 (SD 0.01)

PAPER

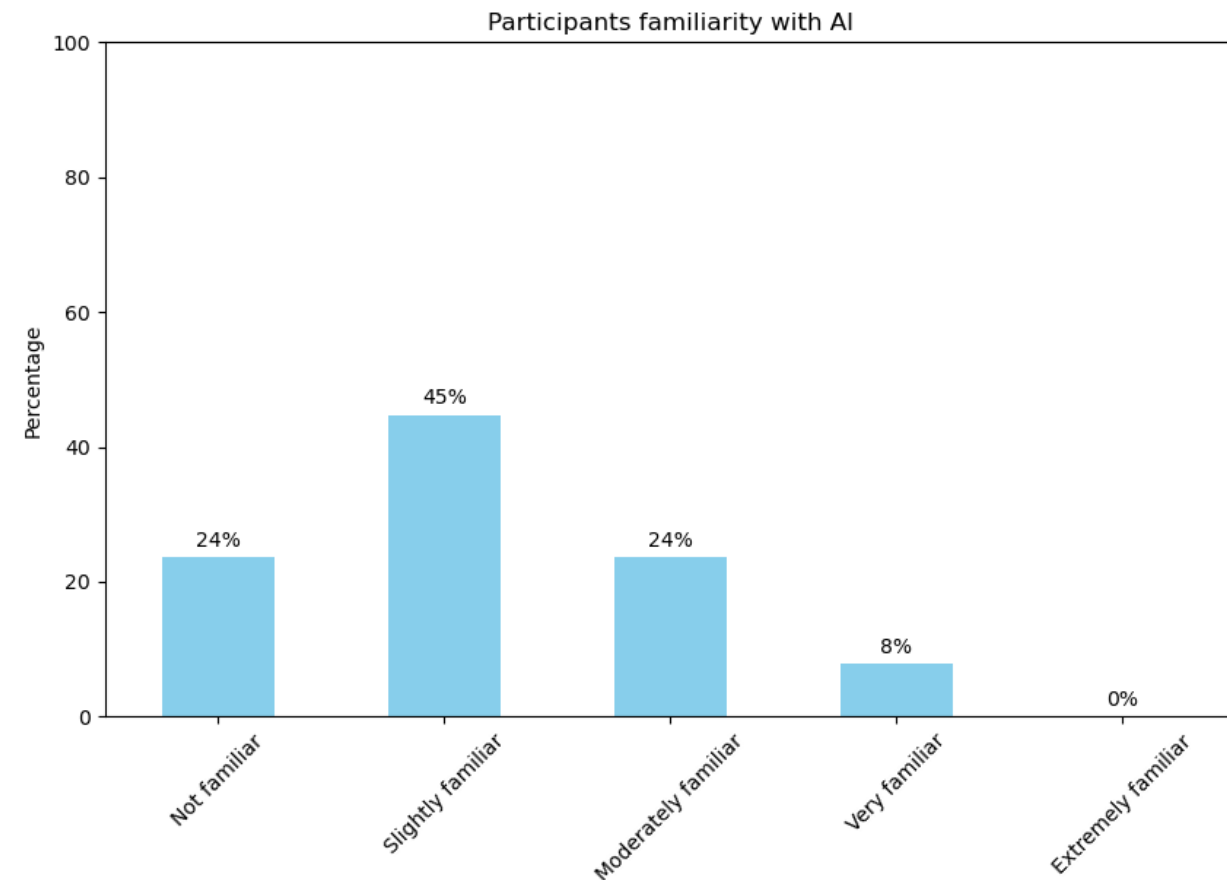
nature
communications



Forty-two clinicians completed the study with most UK consultant level and specializing in infectious disease.

42 PARTICIPANTS

Demographic	No. (%) of participants
Grade	
Consultant	26 (61.90%)
Other	16 (38.10%)
Medical Speciality	
Infectious Diseases	14 (33.33%)
Microbiology	12 (28.57%)
Pharmacist	6 (14.29%)
Other	10 (23.81%)
Sex	
Male	23 (54.76%)
Female	19 (45.24%)
Age	
20s	4 (9.52%)
30s	17 (40.48%)
40s	12 (28.57%)
50s	6 (14.29%)
60s	2 (4.76%)
Prefer not to say	1 (2.38%)
Age Statistics	
Mean	42
Median	37
Standard Deviation	8.84



The AI-IVOS CDSS has a greater impact on clinician's decision making when it recommends don't switch.

NO DIFFERENCES

11/12 cases

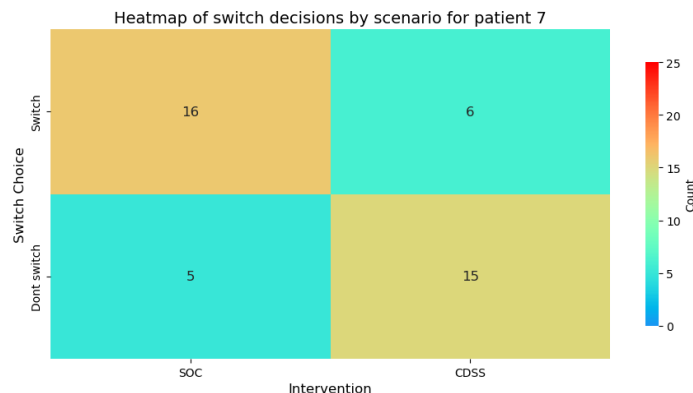


TAKAWAYS

- Prescribing decisions are **nuanced** and **complex**
- Clinicians could correctly identify incorrect AI recommendations and **ignore the support**

STATISTICALLY SIGNIFICANT DIFFERENCES

Patient 7 and subgroup analysis for 3 patients



- The system has a **greater influence** on clinicians when it recommends **don't switch**
- Participants were **persuaded to take the option perceived as safer** which matches the culture of cautiousness (40%) and hesitancy to change (24%) reported in interviews.

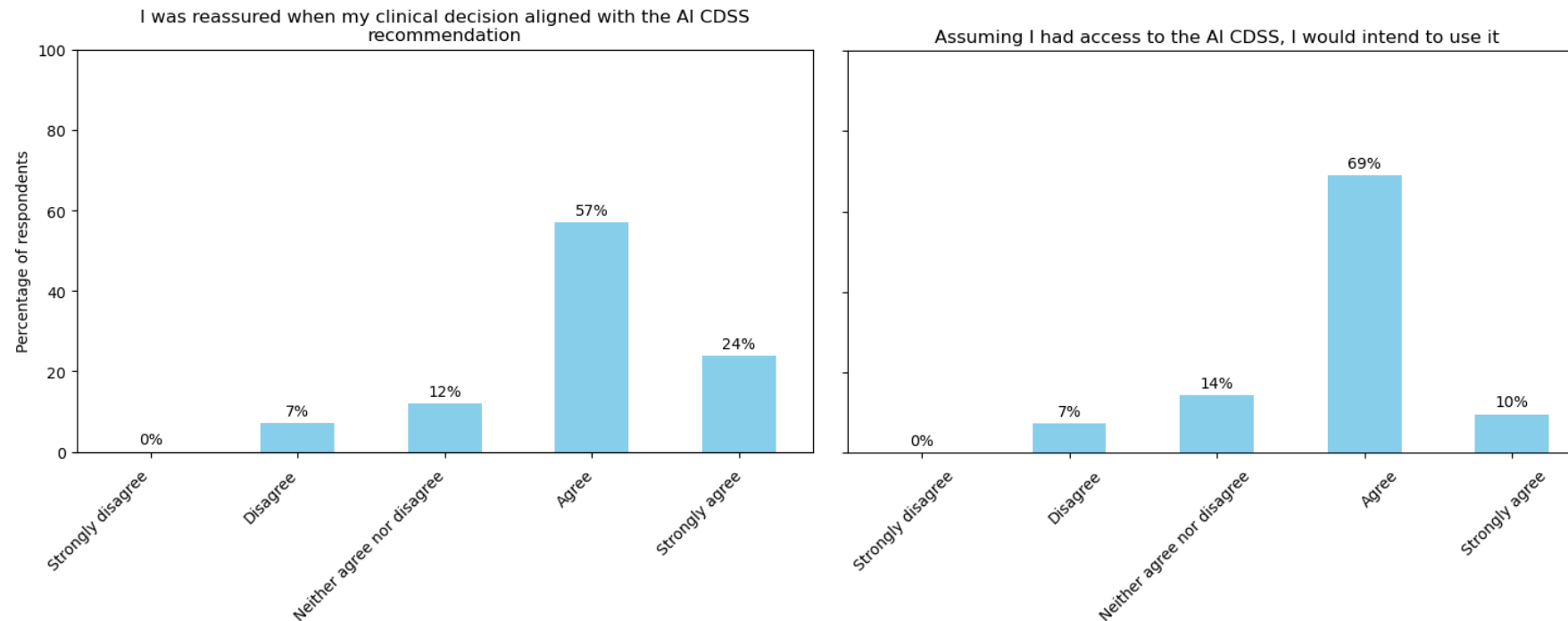
The technology was useful, usable and perceived well by participants.

System Usability score: 72.32 / 100

Perceived ease of use: 3.83 / 5

Perceived usefulness: 3.59 / 5

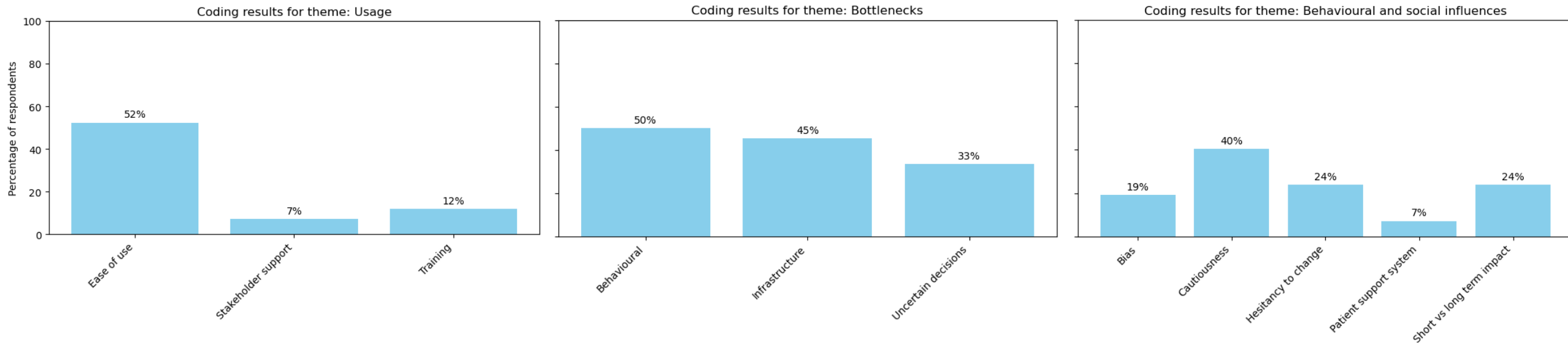
Self efficacy: 4.05 / 5



TAKAWAYS

- Clinicians are **reassured** and more confident when given AI recommendations
- The AI CDSS was well perceived being **useful, usable and appropriate**

Numerous barriers exist to implementing AI technology with evidence and the system being easy to use essential for adoption.



TAKAWAYS

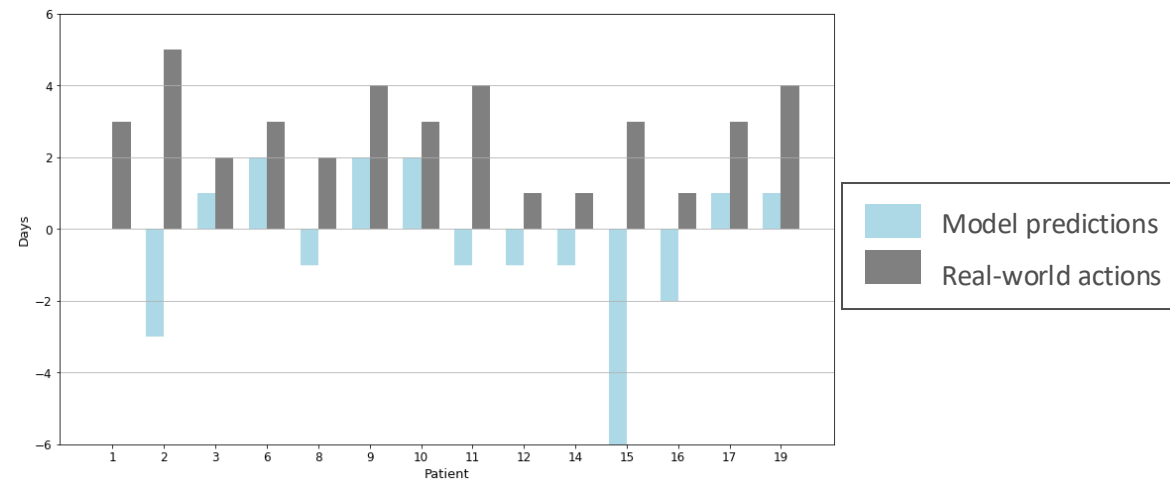
- There was disagreement on whether healthcare institutions have the necessary **infrastructure to support AI technology**
- **Behavioural factors** such as cautiousness play an important role in antimicrobial prescribing and can act as a **barrier** to technology adoption
- Trust in AI-CDSSs is built through **clinical evidence**, with **ease of use** being essential for adoption

Preliminary prospective evaluation was conducted on 40 patients at Imperial NHS Trust against pharmacists' recommendations.

Metric	Result
AUROC	0.68
Accuracy	0.70
FPR	0.28

Temporal difference	Percentage
Early	37.50
Same day	32.50
Late	30

Overall absolute temporal difference of **1.23 days** (SD 1.42)



TAKAWAYS

- **Reasonable performance** on small patient sample with a slight preference for **early predictions**
- Such prospective evaluation is essential for highlighting the AI systems **successes and pitfalls**

This AI CDSS was perceived well and has a greater influence on clinicians when it recommends don't switch.

Future Work



Prospective validation



Clinical translation and adoption

Conclusion

- Clinical decision support system can often have **unexpected impacts on decision making**, such as this system having a greater influence when it recommends don't switch.
- This artificial intelligence system has **potential** to support antibiotic stewardship through **optimising antibiotic switch decision making**
- **Numerous barriers exist** to implementing AI technology including **behaviour change** with further prospective validation required to gather **evidence on the safety and clinical benefit** of the system
- **Studies such as this are essential** for **engaging with end users** and understanding the potential impact and performance of AI technology

I would like to acknowledge the contribution of the following individuals.

Dr Tim Rawson

Professor Pantelis Georgiou

Professor Alison Holmes

Dr Mark Gilchrist

Mr Richard Wilson

Thank you!

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4th December 2024

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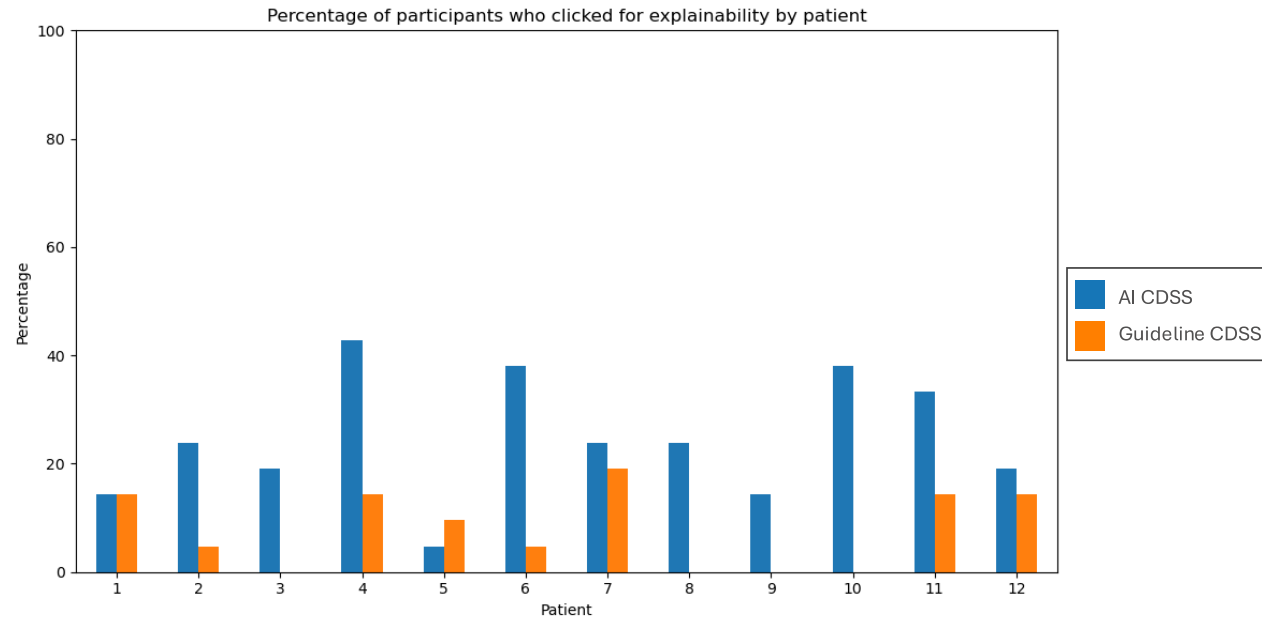


GitHub



Explanations are likely to be underutilized in real clinical practice due to time constraints on decision making .

	Percentage of participants that clicked	
	At any time	When available
AI CDSS explanations	55%	9%
Guideline CDSS explanations	29%	5%



TAKAWAYS

- CDSS explanations were **not frequently used when available**
- Implying that it was the **presence of an AI recommendation** itself driving changes in decision making
- Explainability methods including displaying **similar** patients (including their outcomes) and summarizing information in **free text** warrants further research

Case vignette details.

Patient	Intervention		AI CDSS recommendation	Guideline CDSS recommendation	Ground Truth	Data	Group
	Arm A	Arm B					
1	CDSS	SOC	Don't switch	Don't switch	Don't switch	ICHT	AI correct
2	SOC	CDSS	Switch	Switch	Switch	ICHT	AI correct
3	SOC	CDSS	Switch	Don't switch	Don't switch	ICHT	AI incorrect
4	CDSS	SOC	Don't switch	Switch	Switch	ICHT	AI incorrect
5	SOC	CDSS	Switch	Don't switch	-	ICHT	Uncertain
6	CDSS	SOC	Don't switch	Switch	-	ICHT	Uncertain
7	CDSS	SOC	Don't switch	Don't switch	Didn't switch	MIMIC	AI correct
8	SOC	CDSS	Switch	Switch	Switched	MIMIC	AI correct
9	SOC	CDSS	Potentially switch	Switch	Didn't switch	MIMIC	Uncertain
10	CDSS	SOC	Don't switch	Switch	Switched	MIMIC	AI incorrect
11	CDSS	SOC	Switch	Don't switch	Didn't switch	MIMIC	AI incorrect
12	SOC	CDSS	Potentially switch	Don't switch	Switched	MIMIC	Uncertain

Table 1: Details of the experimental setup and case vignettes.

Screenshots of the web app used for the case vignette experiment.

A

Case Vignette

Patient 1

Details

Age: 73
Sex: Male
Ethnicity: White
Index of multiple deprivation: 5
Co-morbidities: Diabetes
Diagnosis: Pneumonia
Antibiotic treatment: IV co-amoxiclav for 1 day

Vitals

Vitals / Time (hours)	0	6	12	18	24	30
Temperature	37.57	38.49	38.33	38.39	38.37	39.23
Respiratory Rate	19.44	19.55	22.04	20.34	21.50	21.6
Heart Rate	85.57	86.41	107	106.55	116.24	121.62
Systolic Blood Pressure	144.65	143.39	127.32	134.63	135.43	126.16
Diastolic Blood Pressure	78.84	78.49	76.41	77.28	78.4	75.95
Mean Arterial Pressure	112.1	110.82	102.89	105.85	106.83	107.05
SpO2	94.46	94.24	94.53	95.2	94.34	95.05
Glasgow Coma Score	14	15	13	14	14	15
Conscious Level	Alert	Alert	Alert	Alert	Alert	Alert
Supplemental Oxygen	Yes	Yes	Yes	Yes	Yes	Yes

Recommendations

▲ AI CDSS Prediction: [Don't switch](#)

▲ NICE Guidelines: [Reassess in 24 hours](#)

Your Decision

Please choose an action:
Select an option

Please explain your choice:

[Submit](#)

[Back to All Patients](#)

AI CDSS Explanations

Patient 1 - AI CDSS Prediction Details

This patient

Age	Sex	Ethnicity	Index of multiple deprivation	Co-morbidities	Infection diagnosis	AI CDSS prediction	Real action
73	Male	White	5	Diabetes	Pneumonia	Don't switch	TSC

Similar patients

Similar patient	Age	Sex	Ethnicity	Index of multiple deprivation	Co-morbidities	Infection diagnosis	AI CDSS prediction	Real action	Predicted real action
1	65	Male	White	3	Diabetes	Pneumonia	Don't switch	Don't switch	Yes
2	47	Female	White	5	Obesity	Septic	Don't switch	Don't switch	Yes
3	78	Male	Black	7	Hypertension	NG	Don't switch	Don't switch	Yes
4	34	Female	Asian	2	Obstructive pulmonary disease, Obesity	Pneumonia	Switch	Don't switch	No
5	35	Male	Other	6	Septic		Don't switch	Don't switch	Yes

Heatmap indicating the similarity between this patient and the similar patients vitals

AI insights

Four out of five similar patients had a prediction of 'Don't switch' from the AI model and the real action taken was also 'Don't switch', which aligns with the prediction for the patient in question.

In the last 24 hours, the patient's temperature (38.37C) and heart rate (121.62) have increased slightly, which could be a sign of infection.

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Guideline CDSS Explanations

Patient 1 - Guideline Details

Personal Guideline Flowchart

Does your patient have an infection that may require special consideration?

No

Is the patient's gastrointestinal tract functioning with no evidence of malabsorption?

Yes

Is the patient's swallow or enteral tube administration safe?

Yes

Are there any significant concerns over patient adherence to oral treatment?

No

Has the patient vomited within the last 24 hours?

No

Are the patient's clinical signs and symptoms of infection improving?

No

Don't switch

Reassess in 24 hours

UKHSA IVOS Guidelines

[Guidelines Link](#)

Antimicrobial Intravenous-to-Oral Switch (IVOS) Decision Aid

Based on the National Antimicrobial IVOS Criteria

On produced through a UK-wide multicentre survey involving 279 participants

Why use this IVOS decision aid?

With a growing number of antimicrobial resistance (AMR) threats, it is essential to ensure that patients receive the most appropriate antimicrobial therapy. This decision aid is designed to help clinicians make the best decision for their patient, based on the latest evidence and clinical guidelines.

When to use this IVOS decision aid?

This decision aid is intended for use when a patient is on intravenous (IV) antimicrobial therapy and you are considering switching them to oral therapy. It is not intended for use when a patient is on oral therapy or when a patient is on IV therapy for a non-infectious condition.

How your patient has an infection that may require special consideration?

Patients with an infection that may require special consideration are those who have a severe infection, a life-threatening infection, or a complex infection. These patients may require special consideration when deciding whether to switch from IV to oral therapy.

When to use this IVOS decision aid?

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B

Case Vignette

Patient 3

Details

Age: 55
Sex: Male
Ethnicity: Asian
Antibiotic treatment: IV for 3 days

Vitals

Vitals / Time (hours)	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Temperature	37.2				36.41				36.99			36.67		
Respiratory Rate	23.03	15.04	22.86	22.11	24.93	16.0	25.99	25.08	22.07	22.01	25.02	24.96	24.9	31.98
Heart Rate	106.74	135.09	124.05	126.96	101.1	120.99	98.04	82.05	108.99	106.03	116.05	99.02	92.95	93.01
Systolic Blood Pressure	150.03	171.95	178.06	192.03	199.07	163.97	107.99	171.12	157.95	166.99	159.06	146.03	148.03	159.06
Diastolic Blood Pressure	103.04	96.71	116.07	101.96	113.99	110.05	96.03	105.03	110.02	106.0	94.96	102.01	94.0	105.05
Mean Blood Pressure	121.99	120.0	136.02	173.03	133.92	122.99	112.04	122.92	126.99	114.99	116.0	109.92	107.95	
SpO2	92.95	88.99	96.01	85.97	94.12	88.95	95.96	96.99	92.01	91.9	86.97	92.99	93.96	95.09
Glasgow Coma Score - eye opening	5.0								4.0					
Glasgow Coma Score - verbal response	6.0								6.0					
Glasgow Coma Score - motor response	6.0								4.0					
Glasgow Coma Score	16.0								16.0					

Recommendations

▲ AI CDSS Prediction: [Don't switch](#)

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Your Decision

Please choose an action:
Select an option

Please explain your choice:

[Submit](#)

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AI CDSS Explanations

Patient 3 - AI CDSS Prediction Details

This patient

Age	Sex	Ethnicity	Index of multiple deprivation	Co-morbidities	Infection diagnosis	AI CDSS prediction	Real action		
55	Male	Asian	0.29	0.01	0.24	0.42	0.65	Switch	Don't switch

Similar patients

Similar patient	Age	Sex	Ethnicity	Index of multiple deprivation	Co-morbidities	Infection diagnosis	AI CDSS prediction	Real action	Predicted real action	
1	55	Male	Asian	0.29	0.01	0.24	0.42	0.65	Switch	Don't switch
2	55	Male	Asian	0.29	0.01	0.24	0.42	0.65	Switch	Don't switch
3	55	Male	Asian	0.29	0.01	0.24	0.42	0.65	Switch	Don't switch
4	55	Male	Asian	0.29	0.01	0.24	0.42	0.65	Switch	Don't switch
5	55	Male	Asian	0.29	0.01	0.24	0.42	0.65	Switch	Don't switch

Heatmap indicating the similarity between this patient and the similar patients vitals

AI insights

The patient's vitals are similar to Patient 3 who was successfully switched from IV to oral antibiotics. However, other similar patients (Patient 2 and 4) with whom the patient also has some vital similarity, were not switched to oral antibiotic despite the AI CDSS predicting switch.

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Guideline CDSS Explanations

Patient 3 - Guideline Details

Personal Guideline Flowchart

Does your patient have an infection that may require special consideration?

No

Is the patient's gastrointestinal tract functioning with no evidence of malabsorption?

Yes

Is the patient's swallow or enteral tube administration safe?

Yes

Are there any significant concerns over patient adherence to oral treatment?

No

Has the patient vomited within the last 24 hours?

No

Are the patient's clinical signs and symptoms of infection improving?

No

Don't switch

Reassess in 24 hours

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Shannon entropy results from the case vignette experiment.

Patient	Shannon entropy
1	0.00
2	0.28
3	0.78
4	0.28
5	0.28
6	0.45
7	1.00
8	0.97
9	0.53
10	1.00
11	1.00
12	0.94

Table 9: Shannon entropy values for the switch decisions made by participants for each patient. Note due to two options (i.e., switch or dont switch) the minimum and maximum possible Shannon entropy values are 0 and 1 respectively.

Our work on artificial intelligence for optimised antibiotic decision making.

STAGES OF ANTIBIOTIC DECISION MAKING

Hospital admission



0

Antimicrobial
stewardship

1

2

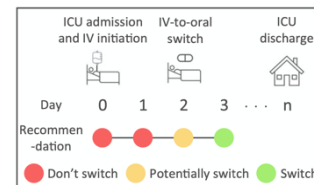
Hospital discharge



3



IV-to-oral switch



Antibiotic readmission

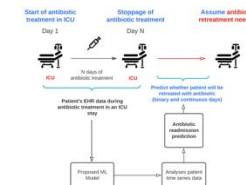


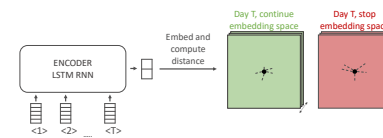
Figure 1.2: Proposed ML-based decision support model

Side effects



Figure 1.3: Implicit dataset formation workflow.

Antibiotic cessation



nature
communications

frontiers
in Digital Health



Using AI to optimize antimicrobial prescribing raises important ethical questions.

ETHICAL VIEWPOINT

Comment

<https://doi.org/10.1038/442256-022-00558-5>

Developing moral AI to support decision-making about antimicrobial use

William J. Bolton, Cosmin Badea, Pantelis Georgiou, Alison Holmes and Timothy M. Rawson

The use of decision-support systems based on artificial intelligence approaches in antimicrobial prescribing raises important moral questions. Adopting ethical decision-making approaches to support decision-making is morally right is often unclear. Incorporating such concepts into AI systems is complex but may be supported by the development of a consensus on the optimal approach to decision-making in this context. In this article, we aim to explore potential ethical frameworks and nuances that may be applied to define what is ethical or not during the development of AI-based clinical decision-support systems (CDSSs).

[Check for updates](#)



Variables	Description	Exemplar of starting antimicrobial treatment	Corresponding ad-hoc utility value
Intensity	How strong is the pleasure?	Treating a relevant infection with antimicrobials has the potential to save that person's life	Highly positive utility
Duration	How long will the pleasure last?	Any extension of life is immeasurable while it is reasonable AMR will continue in the near-term future	Positive utility
Certainty or uncertainty	How likely or unlikely is it that the pleasure will occur?	Limited information often means treatment may or may not be helpful and there is always an inherent risk of developing AMR	Neutral utility, without more information
Propinquity	How soon will the pleasure occur?	Treatment can be effective immediately however the same is true for the evolution of AMR	Neutral utility, without more information
Fecundity	The likelihood of further sensations of the same kind	-	Unable to assign
Purity	The likelihood of not being followed by opposite sensations	-	Unable to assign
Extent	How many people will be affected?	Prescribing antimicrobials effects the patient and those close to them, while the development of AMR is a certainty and may affect everyone, causing significant suffering and mortality	Immense negative utility

Patient and clinician views have been considered, with the public and stakeholder educated.

EDUCATION



PRIMARY RESEARCH

