



University of Colorado **Anschutz Medical Campus**

Background and Demographics

Crush Syndrome in Resource-Constrained Environments: Modified Delphi Survey #1

Thank you for your participation!

Q1.1. Please confirm that you have reviewed the informed consent document and that you consent to participate in this study.

☐ Yes, I consent.

Q1.2. What is your name? (First name, Last name)

. The following demographic questions will be presented in aggregate. No personal identifying information will be included in any publications from this work.

Q1.3. What is your sex?

- ☐ Male
- ☐ Female
- ☐ Non-binary / third gender
- ☐ Prefer not to say

Q1.4. What is your age?

Q1.5. What is your medical specialty?

Q1.6. What is your professional title?

Q1.7. What is your institutional affiliation?

Q1.8 . What is your nationality?

Q1.9. How many years of clinical experience do you have?

(Year 1 would be the first year following graduation from medical school or equivalent).

Round One Survey Questions

. In this section, we want to learn more about your own clinical experience and work environment. Answer according to your own definitions of clinical syndromes.

Q2.1. Over the course of your professional career, how many patients have you diagnosed with **traumatic crush injury** ?

(Answer according to your own personal definition of crush injury)

- ☐ 0 cases
- ☐ 1 to 10 cases
- ☐ 10 to 50 cases
- ☐ Greater than 50 cases

Q2.2. Please describe how often the following **mechanisms of injury** contributed to traumatic crush injury in the patients you have cared for.

	Never seen	Rarely seen	Sometimes seen	Often seen
Community assault (i.e. patient beaten by multiple persons, often with whips or rods)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Entrapment (e.g. vehicular entrapment, stuck under rubble)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other mechanism	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q2.3. Please elaborate on other mechanisms of injury that contributed to traumatic crush injury that you have treated.

Q2.4. Over the course of your professional career, how many patients have you diagnosed with **traumatic crush syndrome**?

(Answer according to your own personal definition of crush syndrome)

- ☐ 0 cases
- ☐ 1 to 10 cases
- ☐ 10 to 50 cases
- ☐ Greater than 50 cases

Q2.5.1. Please describe the geographies in which you have cared for patients with **crush syndrome** over the course of your career.

Please check all that apply.

- ☐ Urban
- ☐ Rural
- ☐ Austere

Q2.5.2. Please describe the countries in which you have cared for patients with **crush syndrome** over the course of your career.

Please check all that apply.

- ☐ USA
- ☐ South Africa
- ☐ Turkey
- ☐ Other Country

Q2.5.3. Please describe the clinical environment(s) in which you have cared for patients with **crush syndrome** over the course of your career.

Please check all that apply.

- ☐ Military
- ☐ Civilian
- ☐ Disaster Response

Q2.5.4. Please describe the clinical location(s) in which you have cared for patients with **crush syndrome** over the course of your career.

Please check all that apply.

- ☐ Prehospital
- ☐ Emergency Center/Department
- ☐ Intensive Care Unit
- ☐ Ward (Inpatient floor)
- ☐ Operative theatre

Q2.5.5. Please describe the the facility type(s) in which you cared for patients with **crush syndrome** over the course of your career.

Please check all that apply

- ☐ Surgically capable hospital/facility/setting
- ☐ Light surgical hospital/facility/setting
- ☐ Non-surgically capable hospital/facility/setting

Q2.6. In a few sentences, please provide more context about the clinical environment(s) in which you have cared for patients with **crush syndrome** over the course of your career.

Q2.7. In a few sentences, please provide more context about the clinical environment(s) in which you **currently practice**.

. In this section, we request your feedback on clinical definitions. These definitions will be used for predictive model development.

Q3. The following are proposed definitions for **crush injury**:

Definition 1: "The local manifestation of direct physical trauma, and can present as muscle injury and swelling,

along with possible muscle necrosis and neurologic dysfunction in the affected areas. It can be due to the primary direct effect of trauma or ischemia-reperfusion injury related to compression.” (Haines & Doucet, 2021).

Definition 2: "An injury caused as a result of direct physical crushing of the muscles due to something heavy." (Rajagopalan, 2010).

How would you define crush injury?

- ☐ Definition 1, unchanged
- ☐ Definition 2, unchanged
- ☐ Other: I have my own definition, or I would modify or combine the above definitions

Q3.1. Please provide your definition of crush injury and explain why you prefer this definition over other options.

Q4. The following are proposed definitions for **crush syndrome**:

Definition 1: “The systemic manifestation of crush injury, which can result in acute kidney injury, multisystem organ injury or death.” (Haines & Doucet, 2021).

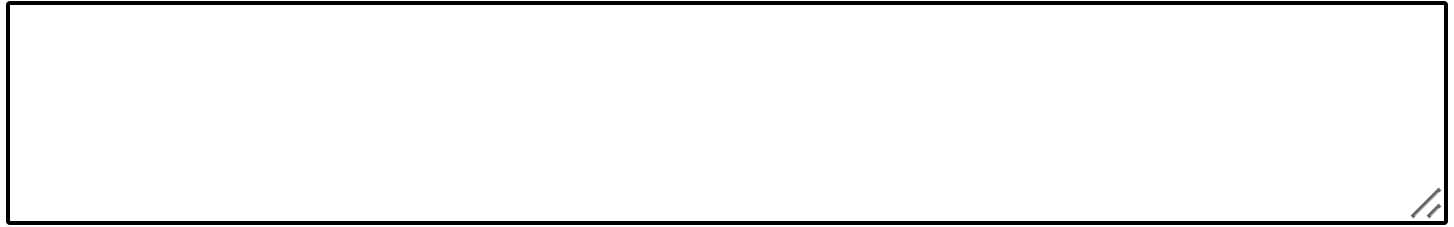
Definition 2: "A series of metabolic changes produced due to an injury of the skeletal muscles of such a severity as to cause a disruption of cellular integrity and release of its contents into the circulation." (Rajagopalan, 2010).

Definition 3: "An injury in which patients suffer from extensive muscle damage, leading to devastating sequelae of hemodynamic and metabolic disturbances and, most of all, acute renal failure." (Jun et al, 1997).

How would you define crush syndrome?

- ☐ Definition 1, as is
- ☐ Definition 2, as is
- ☐ Definition 3, as is
- ☐ Other: I have my own definition, or I would modify or combine one of the above definitions.

Q4.1. Please provide your definition of crush syndrome and explain why you prefer this definition over the other options.



Q5. The following are proposed definitions for **acute kidney injury**:

Definition1: KDIGO

The Kidney Disease: Improving Global Outcomes Guideline (KDIGO) defines AKI as:

- Increase in serum creatinine by ≥ 0.3 mg/dL (≥ 26.5 micromol/L) within 48 hours OR
- Increase in serum creatinine to ≥ 1.5 times baseline within 7 days OR
- Urine output < 0.5 ml/kg/hr for ≥ 6 h

Definition 2: RIFLE

The Acute Dialysis Quality Initiative RIFLE criteria defines AKI as:

- Increase in serum creatinine ≥ 1.5 times baseline within 48 hours OR
- Decrease in GFR $\geq 25\%$ within 48 hours OR
- Urine output < 0.5 mL/kg/hr for ≥ 6 h

How would you define acute kidney injury?

- ☐ Definition 1 - KDIGO - as is
- ☐ Definition 2 - RIFLE - as is
- ☐ Other: I have my own definition, or I would modify or combine the above definitions.

Q5.1. Please provide your definition of acute kidney injury, and explain why you prefer this definition over the other options.



Q6. The following are proposed definitions for **acute renal failure**.

Definition 1: KDIGO

- Increase in serum creatinine to ≥ 3 times baseline OR
- Increase in serum creatinine of ≥ 0.3 mg/dL to absolute value ≥ 4 mg/dL [increase in serum creatinine of ≥ 26.5 $\mu\text{mol/L}$ to an absolute value ≥ 354 $\mu\text{mol/L}$] OR
- Urine output of < 0.3 mL/kg/hour for ≥ 24 hours or anuria for ≥ 12 hours OR
- Initiation of renal replacement therapy (dialysis)

Definition 2: RIFLE

- Increase in serum creatinine to ≥ 3 times baseline OR
- Decrease in GFR by 75% or more OR
- Increase in serum creatinine of ≥ 0.5 mg/dL to absolute value ≥ 4 mg/dL [increase in serum creatinine of ≥ 44 $\mu\text{mol/L}$ to an absolute value ≥ 354 $\mu\text{mol/L}$] OR
- Urine output < 0.3 mL/kg/hour for ≥ 24 hours or anuria for ≥ 12 hours OR
- Initiation of renal replacement therapy (dialysis)

Definition 3: Initiation of renal replacement therapy.

How would you define acute renal failure?

- ☐ Definition 1: KDIGO
- ☐ Definition 2: RIFLE
- ☐ Definition 3: Initiation of renal replacement therapy (dialysis)
- ☐ Other: I have my own definition, or I would modify or combine the above definitions.

Q6.1. Please provide your definition of acute renal failure, and explain why you prefer this definition over the other options.

Q7. Do you consider the terms **crush syndrome** and **traumatic rhabdomyolysis** to be equivalent and interchangeable?

- ☐ Yes - the terms are equivalent and interchangeable
- ☐ No - the terms are not equivalent or interchangeable

Q7.1. Please explain the relationship between crush syndrome and traumatic rhabdomyolysis. How do these two diagnoses differ from one another?

Q8. Do you consider **crush syndrome** to be a spectrum of disease?

- ☐ Yes – crush syndrome is a spectrum of disease
- ☐ No - crush syndrome is not a spectrum of disease

Q8.1. Please describe how you would further classify the spectrum of **crush syndrome** (eg. mild/moderate/severe). Please provide definitions for each subcategory of your choosing.

Q8.2. Please explain why you believe that **crush syndrome** is NOT a spectrum of disease.

. In this section, we will seek to understand the clinical tools you utilize in the diagnosis and management of crush syndrome.

Q9. What resources are available in your place of work where you are treating patients with **crush syndrome**?

(check all that apply)

- ☐ Ability to monitor hourly urine output
- ☐ Point-of-care ultrasound
- ☐ Nasal cannula oxygen therapy
- ☐ CPAP or BIPAP therapy
- ☐ Ventilator support
- ☐ Dialysis capability
- ☐ Intensive care unit on site

Q10. **HOW OFTEN** are you able to **access** the following laboratory data on your patients with crush injury in your place of work within a time frame that is useful for clinical decision-making?

	Never	Sometimes	About half the time	Most of the time	Always
Urine dipstick	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Urine microscopy for red blood cells	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	Never	Sometimes	About half the time	Most of the time	Always
Urine myoglobin	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum bicarbonate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum calcium	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum creatine kinase (CK or CPK)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum creatinine	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum lactate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum myoglobin	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum pH	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum phosphate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum potassium	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum urea	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q11. Please indicate how **USEFUL** the following clinical or laboratory data are in the **DIAGNOSIS** of **crush syndrome** in your clinical practice environment.

	Not useful	Slightly useful	Moderately useful	Very useful	Extremely useful	Cannot comment
Urine output	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Urine dipstick	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Urine microscopy for red blood cells	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Urine myoglobin	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum bicarbonate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum creatine kinase (CK or CPK)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum calcium	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum creatinine	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum lactate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum myoglobin	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum pH	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum phosphate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum potassium	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum urea	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q12. Please indicate how **USEFUL** the following clinical or laboratory data are in the **PROGNOSTICATION** of patients with **crush syndrome** in your clinical practice environment.

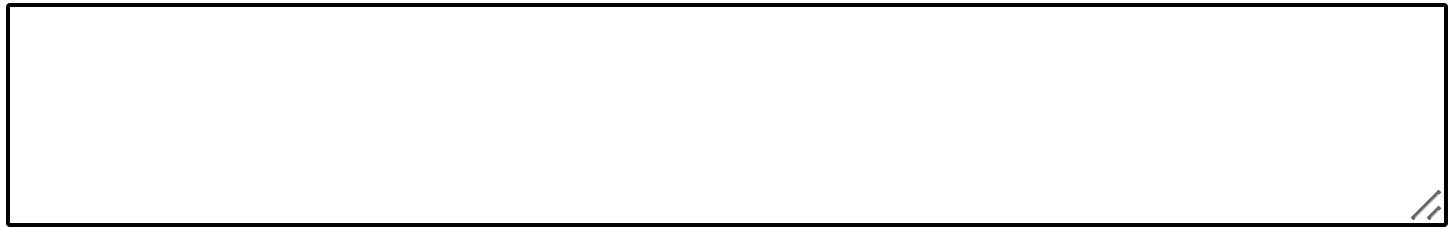
Think about how these variables help you make disposition decisions for these patients (eg. where to transport, what level of care, whether to transfer to other facility).

	Not useful	Slightly useful	Moderately useful	Very useful	Extremely useful	Cannot comment
EKG	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Urine output	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Urine dipstick	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Urine microscopy for red blood cells	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum bicarbonate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum creatine kinase (CK or CPK)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum calcium	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum creatinine	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum lactate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum myoglobin	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum pH	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum phosphate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum potassium	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Serum urea	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

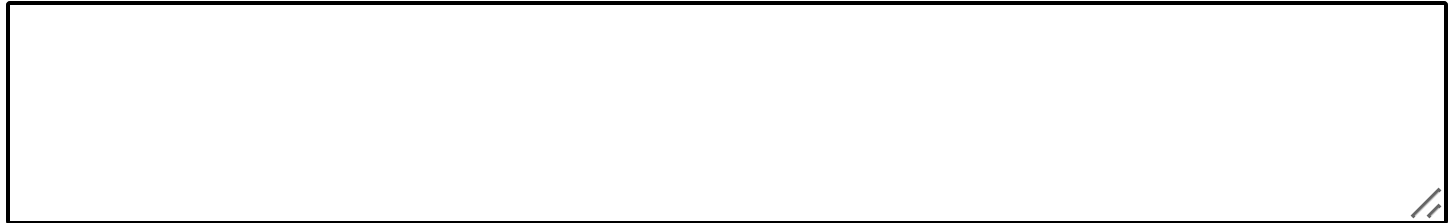
Q13. Are there any other laboratory data or clinical variables (including vital signs, physical exam findings) not listed above that you routinely use for the **DIAGNOSIS** of **crush syndrome**?

Q14. Are there any other laboratory data or clinical variables (including vital signs, physical exam findings) not listed above that you routinely use for **PROGNOSTICATION** of patients with **crush syndrome**?

Q15. How does **time since injury** affect your decision making and use of data?



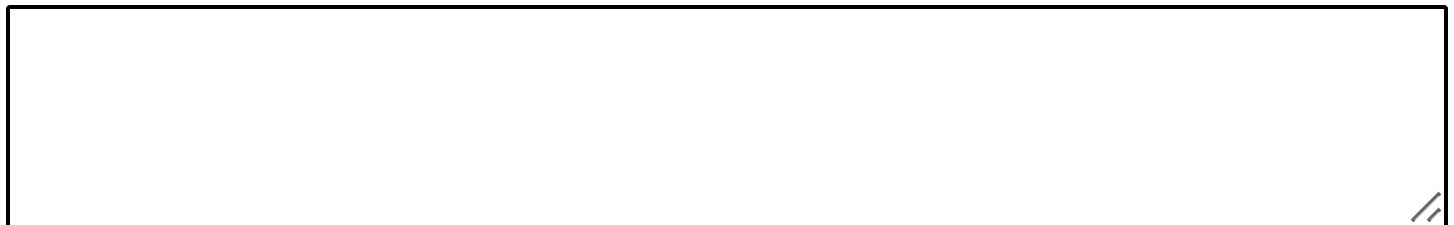
Q16. Please explain if/how you use **serial re-examinations or testing** to arrive at clinical decisions for patients with crush injury.



Q17. Do you support the use of total body surface area that has sustained soft tissue injury (via the rule of 9's similar to that used for burn patients) in the prediction of **crush syndrome** for patients with crush injury?

- ☐ Yes, completely supported
- ☐ Yes, but I have reservations
- ☐ No, not supported
- ☐ Not familiar with this tool

Q17.1. Please provide justification for your response above regarding use of total body surface area injured in prediction of crush syndrome.



Q18. Do you support the use of point-of-care soft tissue ultrasound in the prediction of **crush syndrome** for patients with crush injury?

- ☐ Yes, completely supported
- ☐ Yes, but I have reservations
- ☐ Not, not supported
- ☐ Not familiar with this tool

Q18.1. Please provide justification for your response above regarding use of soft tissue ultrasound in prediction of crush syndrome.

Q19. We aim to develop a clinical predictive tool for the diagnosis and prognostication of **crush syndrome**. Please help us identify the time point at which such a clinical tool would be most useful.

Please rank the following (top being your most preferred time point):

The clinical predictive tool should incorporate data obtained within...

<div>↑</div> <div>↓</div>	4 hours of emergency department arrival	<div>↑</div> <div>↓</div>
	6 hours of emergency department arrival	
	8 hours of emergency department arrival	
	12 hours of emergency department arrival	
	24 hours of emergency department arrival	
	Some other time point	

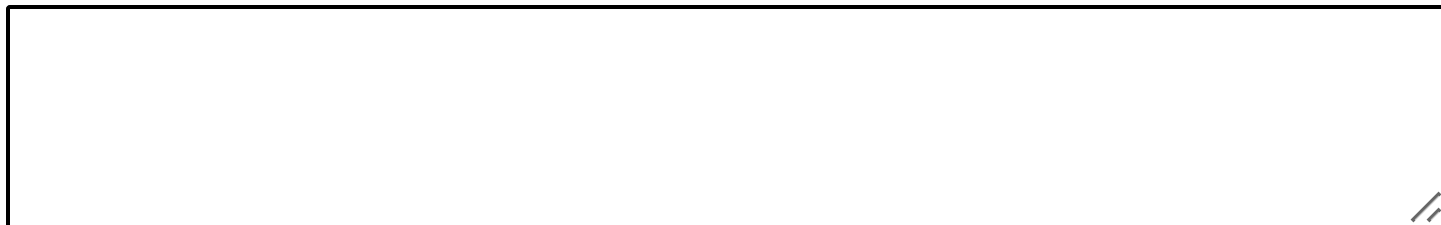
Q19.1. Please explain your rationale for preferred time point. If you prefer 'some other time point,' please elaborate.

Q20. What clinical outcomes do you think are most important to predict for patients with **crush syndrome**?

Please rank from most to least important (top being most important).

<div>↑</div> <div>↓</div>	Development of acute kidney injury	<div>↑</div> <div>↓</div>
	Need for renal replacement therapy (dialysis)	
	Need for respiratory support (hypoxia requiring oxygen administration)	
	Need for aggressive circulatory support (hypotension requiring IV fluids)	
	Need for hospital admission	
	Need for intensive care unit admission	
	Mortality at 7 days	
	Other outcome	

Q20.1. Please explain your rationale above regarding the most important clinical outcomes to predict. If you prefer some 'other outcome,' please elaborate.



Q21. Do you believe the clinical predictive model should predict a COMPOSITE outcome?

(Multiple endpoints are combined in a composite outcome. For example, combining need for dialysis, ICU admission or death, would be a composite outcome).

- ☐ Yes
- ☐ No

Q21.1. Please elaborate on the variables you would include in this composite outcome.

(Should the clinical predictive model include a combination of outcomes? Which outcomes should be combined for the clinical predictive tool?)



Q21.2. Please elaborate on why the model should not predict a composite outcome.



Q22. Please provide any final comments or suggestions.



. Thank you so much for taking the time to respond to the first round survey for this modified Delphi process. Your expertise is greatly valued. We will be in touch with round two within the next 4 - 6 weeks.

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