UNIVERZITA KARLOVA

3. lékařská fakulta

Disertační práce

MUDr. Metoděj Renza

Praha 2025

UNIVERZITA KARLOVA

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Disertační práce

Studijní program: Preventivní medicína a epidemiologie

Vliv výuky studentů a zdravotnických profesionálů metodami simulační medicíny na výsledky didaktického testování a klinické výstupy v přednemocniční a nemocniční péči.

The impact of teaching students and healthcare professionals using simulation medicine methods on the results of didactic testing and clinical outcomes in pre-hospital and hospital care.

Školitel: MUDr. Roman Sýkora, Ph.D., MHA

Pracoviště: Klinika anesteziologie a resuscitace Fakultní nemocnice Královské Vinohrady a 3. lékařské fakulty Univerzity Karlovy

Prohlášení:

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V Praze dne 15. června 2025

MUDr. Metoděj Renza

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Identifikační záznam:

RENZA, Metoděj. Vliv výuky studentů a zdravotníků metodami simulační medicíny na výsledky didaktického testování a klinické výsledky v přednemocniční a nemocniční péči. [The impact of teaching students and healthcare professionals using simulation medicine methods on the results of didactic testing and clinical outcomes in pre-hospital and hospital care]. Praha, 2025. 77 stran. 4 přílohy. Disertační práce. Univerzita Karlova, 3. lékařská fakulta, Klinika anesteziologie a resuscitace, školitel: MUDr. Roman Sýkora, Ph.D., MHA

Klíčová slova: simulace, vzdělávání v medicíně, trénink kompetencí, netechnické dovednosti, medicínská chyba

Key words: simulation, medical education, competence training, non-technical skills, medical error

Poděkování

Především děkuji svému školiteli Romanu Sýkorovi. Roman je nejen mým školitelem, ale především kamarádem, který mě toho v průběhu let mnoho naučil. Poctivá práce v klinické praxi, zodpovědný a kritický přístup ke vědě a jejím výsledkům, ale také rovný a pragmatický postoj k životu samotnému. Děkuji za více než 10 let vedení touto cestou. Chtěl bych také poděkovat všem svým kolegům, se kterými jsme vědecké i další projekty vedli a rozvíjeli. Děkuji všem kolegům, kteří se podíleli na výzkumech a simulačních trénincích, které jsme připravovali. Děkuji Martinu Kolářovi, Kubovi Poláchovi a dalším kolegům, kteří již před více než 10 lety věřili, že simulační medicína má smysl. Děkuji Michalu Sternovi, který mi byl nejen tím nejlepším primářem, ale kamarádem a učitelem psychologie simulační medicíny. Děkuji rodině a přátelům, kteří byli často upozaděni kvůli probíhající práci na projektech a studiích. Děkuji za jejich pochopení. Děkuji celému kolektivu Kliniky anesteziologie a resuscitace Fakultní nemocnice Královské Vinohrady, protože lepší kolegy a kolegyně jsem si do začátku své kariéry nemohl vybrat. Závěrem děkuji domovské 3. lékařské fakultě Univerzity Karlovy za to, jakou je: *rodinná a přátelská*.

V Praze, dne 15. června 2025 Metoděj Renza

1 Úvod

Tato disertační práce je komentovaným souborem publikovaných prací autora. Od zahájení činnosti simulační laboratoře na 3. lékařské fakultě (3. LF UK) Univerzity Karlovy (UK) v roce 2020 bylo cílem připravit stabilní systém vzdělávání zdravotnických pracovníků, jak v pregraduálním, tak i v postgraduálním výcviku. Paralelně s tím tým lektorů simulační medicíny při Klinice anesteziologie a resuscitace Fakultní nemocnice Královské Vinohrady a 3. LF UK zahájil vědeckou práci navázanou na toto simulační centrum. V disertační práci jsou uvedeny komentáře ke studiím, které cílí i mimo zdi lékařské fakulty, avšak v souladu s cíli autorova postgraduálního studia. Cílem této práce je poskytnout ucelenou informaci o pozadí simulačního vzdělávání v kontextu realizovaných výzkumných projektů.

2 Simulační medicína ve vzdělávání zdravotníků

2.1 Současné poznání

Ve stále vyvíjejícím se zdravotnickém prostředí je zajištění poskytování kvalitní zdravotní péče nutností (Issenberg et al. 1999). Nástupem medicínských simulací a výuky založené na simulaci v medicíně se výrazně změnily možnosti dosahování bezpečné zdravotní péče (Aebersold 2016). Simulace v medicínském vzdělávání otevřela nové výzvy a možnosti zdravotnického vzdělávání (Hegland et al. 2017), bezpečnosti a kvality poskytované péče (Herrera-Aliaga and Estrada, 2022).

Simulační medicína zásadně změnila možnosti v lékařském i nelékařském vzdělávání (So et al. 2019; Khan, Pattison, Sherwood 2011 a). Historicky pohlížíme na medicínskou simulaci jako jednoduchý nástroj pro trénink technických dovedností, např. komprese hrudníku při resuscitaci dospělých (Rosen 2008). Simulace dokáže modelovat i komplexní, multidisciplinární situace věrně odrážející klinickou realitu.

Simulační výuka nabízí bezpečné prostředí, ve kterém mohou zdravotníci zdokonalovat své technické dovednosti (kardiopulmonální resuscitace, kanylace cévního řečiště, auskultační vyšetření pacienta) (JB, VR 2004). Umožňuje však i pokročilý trénink netechnických dovedností (role vedoucího týmu, asertivní komunikace, meziprofesní trénink). Medicínská simulace dává příležitost učit se z chyb, které jsou v bezpečném prostředí, jak pro pacienta (skutečný pacient není přítomen), tak pro účastníka (není zatížen rizikem poškození pacienta). Pro bezpečnou výuku frekventantů pre – i postgraduálního vzdělávání je podstatné úvodní seznámení se simulačním prostředím (vybavení, dostupné prostředky, personální obsazení, limity simulačního prostředí) (Rivière et al. 2018).

Simulace nabízí možnosti pro komplexní nácvik postupů, jednoduchých manuálních i týmových dovedností (Jacobsen et al. 2009), vše tak pravděpodobně zlepšuje výsledky léčby pacientů (Weller et al. 2008). Odborné znalosti je možné zlepšovat bez potenciálního poškození pacientů (Smith et al. 2023). V perspektivě zkracující se délky hospitalizace pacientů (Miró et al. 2017; Juan et al. 2006) se jeví simulace jako přístupná alternativa *bedside* výuky zdravotníků.

Kromě toho, tato didaktická metoda našla významné uplatnění v oblasti bezpečnosti a kvality péče o pacienty, tak aby mohla být mezikrokem mezi hypotézou a změnou klinických postupů (Grierson et al. 2019). Ačkoli jsou výhody simulační medicíny patrné, je nutné kriticky analyzovat její efektivní implementaci, omezení a etické aspekty.

2.2 Simulace v perspektivě didaktiky v medicíně

Využívání simulační výuky v medicíně na univerzitní úrovni představuje průnik IT technologií (simulátory) (Fraser et al. 2009), andragogiky (pozadí výuky dospělých) a psychologie. Simulace mění tradiční přístupy k frontální výuce (přednášky, semináře) či způsobu studia studentů či zdravotnických profesionálů. Simulace vytvářejí zážitkové, interaktivní, a především na studenta zaměřené prostředí. Simulační medicína umožňuje studentům získat znalosti, dovednosti a postoje nezbytné pro kvalitní klinickou praxi, která je zároveň bezpečná (Davies and Krame, 2024).

2.3 Úloha simulací při zlepšování zdravotnických dovedností

Přínos medicínských simulací spočívá v poskytnutí bezrizikového, nebo alespoň nízkorizikového prostředí (Khan, Pattison, Sherwood 2011b). Premisou bezpečného vzdělávání v simulacích jsou dvě části, kterou simulace zahrnuje.

- Bezpečnost technická (elektrický proud, ostré předměty, pohyblivé vybavení).
- Bezpečnost psychická (beztrestnost chyby, diskrétnost lektorů a další) (Geraldine Somerville et al. 2023).

Zásadní pro simulační vzdělávání je okamžitá zpětná vazba neboli *debriefing* (Cantrell 2008). Zpětná vazba je nezbytnou součástí pro učení a reflexi v reálném čase. Studenti mohou okamžitě zhodnotit svůj výkon, pochopit své síly, a naopak pochopit nedostatky a oblasti, ve kterých se mohou dále zlepšovat (Levett-Jones and Lapkin, 2014). Smyčka zpětné vazby urychluje křivku učení a podporuje jej (Tremblay et al. 2019). V rámci debriefingu je vždy součástí, jak debata nad možnostmi pro zlepšení, tak analýza správně provedených kroků. Tím se daná kompetence, postup nebo znalost fixuje.

Úspěch simulací závisí na jejich vhodném začlenění do kurikula pregraduálního či celoživotního vzdělávání zdravotníka (Nuzhat et al. 2014; Cate et al. 2018). Poskytnutí motivace a pochopení vzdělávacího konceptu je důležitý motivační bod při učení dospělých. Toto je prvek, který spojuje jak pregraduální, tak postgraduální vzdělávání a je zásadním a definujícím bodem andragogiky (Bryan, Lewis 2021). Podstatné jsou informace a charakteristiky přicházejících frekventantů, jako je jejich vzdělání, délka praxe a typ pracoviště, ze kterého přichází. Tento prvek může být realizován např. dotazníkem v období před kurzem, či rozhovorem a diskusí nad očekáváními a cíli kurzu.

Obtížnost řešených simulací by měla být stupňovitá a adekvátní dosaženým znalostem a dovednostem účastníků. Odchylka oběma směry, kdy je simulace příliš jednoduchá či naopak složitá, přispívá k frustraci účastníků (Fraser, Ayres and Sweller, 2015), která se dále projevuje v celém průběhu kurzu, či dokonce dlouhodobém vzdělávání zdravotníků.

S rostoucí složitostí systémů zdravotní péče se zdůrazňuje potřeba efektivní spolupráce mezi profesemi (sestry, ošetřovatelé, lékaři, záchranáři, další technické profese) (Klipfel et al. 2011). Simulace umožňuje trénovat týmové scénáře, v nichž mohou studenti z různých zdravotnických oborů spolupracovat při řešení simulovaných událostí, což zlepšuje jejich dovednosti v oblasti společného rozhodování mezi danými odbornostmi (Jacobsen et al., 2009; S. Sharma et al., 2011). Na úrovni jednotlivce se lze zlepšovat a tím budovat komunikační dovednosti mezi zdravotníkem a pacientem, např. při simulovaných scénářích s herci tzv. standardizovanými pacienty (Howley et al. 2008).

2.4 Vzdělávání zdravotníků, nabytí kompetencí, a příprava programů k jejich nabytí

Úloha simulace ve výuce medicíny spočívá v oblasti hodnocení a postupného nabývání kompetencí na základě předchozího tréninku (Stoffman 2022). Kompetence je dovednost nebo schopnost jednotlivce či skupiny provádět jednotlivé úkony, jak v rámci diagnostiky, terapie nebo komunikace s pacientem a jeho rodinou. Jedním ze současných trendů ve výuce medicíny je „competence-based medical education“ (CBME). Metoda CBME spočívá ve výcviku, testování, ověřování, a nakonec udělení jednotlivých kompetencí (vyšetření, terapeutická metoda, soubor postupů). Tradiční metody hodnocení výuky totiž často selhávají při hodnocení klinických dovedností, rozhodovacích schopností a týmové interakce. Z tohoto důvodu čím dál častěji je simulační výuka metodou volby (*Competence based education and training: background and origins* 2005). Simulační výcvik se stal (díky bezpečnému a realistickému prostředí) důležitým nástrojem pro získávání a rozvoj kompetencí nejen v lékařském, ale i nelékařském vzdělávání („Competence based education and training: background and origins“, 2005).

3 Preventivní potenciál simulačního vzdělávání

3.1 Prevence chyby v medicíně a práce s chybou

Medicínské chyby jsou definovány jako preventabilní nežádoucí události, jež pacienta poškozují (Reason 2000). Závažnost medicínských chyb se pohybuje od drobných odchylek od standardu péče až po závažná pochybení, která mají za následek trvalé poškození zdraví nebo dokonce smrt (Leape 1994). Ve Spojených státech amerických je preventabilní medicínská chyba stále třetí nejčastější příčinou smrti ve zdravotním systému (Makary, Daniel 2016). Nejbezprostřednějším a nejzávažnějším důsledkem medicínských chyb je trvalé poškození pacienta (James 2013). Analýzu příčin, důsledků a metod prevence medicínských chyb, lze v kontextu simulace přeformulovat do tréninku, který zvyšuje bezpečnost pacientů a promítá se do výsledků zdravotní péče (Bates 2007).

Medicínské chyby vznikají na základě nejrůznějších faktorů, které spolu často souvisejí (Schwappach 2014). K těmto chybám může dojít v důsledku únavy, stresu, nedostatečného vzdělání nebo prostého přehlédnutí okolností (Baker et al., 2004; Soop et al., 2009; Zegers et al., 2009). Efektivní komunikace je ve zdravotnictví zásadní pro kvalitu poskytované péče (Suter et al. 2009). Chybná a neefektivní komunikace mezi zdravotníky, nebo mezi zdravotníky a pacienty, může vést ke snížení dostupnosti informací o zdravotním stavu (Ross and Lin, 2003). K chybám mohou přispívat systémové problémy ve zdravotnických zařízeních, jako nedostatek personálu, nedostatečné vybavení nebo nedostatečné nastavení pracovních procesů (Wittich, Burkle, Lanier 2014; Taib et al. 2011).

Zdravotničtí pracovníci potřebují pravidelná školení, aby byli obeznámeni s nejnovějšími zdravotnickými postupy a normami. Nedostatečné vzdělávání může mít za následek udržování zastaralých či nesprávných postupů, což zvyšuje riziko chyb (Aggarwal et al. 2010). Simulační programy mohou nabývat významu pro udržení a rozšiřování kompetencí a prevenci chyb (Lamé, Dixon-Woods 2020).

Zdravotníci, kteří se dostanou do kontaktu s medicínskou chybou, často zažívají značný psychický stres. Ten se může projevovat jako pocit viny, úzkosti, deprese a v závažných případech posttraumatická stresová porucha (PTSD), s těmito případy je nutné pracovat dál (Wald 2020). Tento jev se označuje jako efekt "druhé oběti", kdy zdravotníci, po takové chybě, mohou prožívat výše zmiňované, stavy velmi nepříjemně. Velmi důležitý je trénink vedoucích pracovníků, aby mohli tyto situace analyzovat a poskytovat podporu zúčastněným (Lane et al. 2018).

Pro prevenci medicínské chyby je taktéž podstatná efektivní komunikace v rámci zdravotnických týmů, mezi zdravotníky a pacienty. Důležité je zavedení standardizovaných komunikačních protokolů, jako je například SBAR (Situation, Background, Assessment, Recomentation) (Müller et al. 2018). Tyto protokoly mohou pomoci zajistit jasnou a konzistentní výměnu informací (Lancaster, Westphal, Jambunathan 2015). Vhodná je také systémová podpora otevřené komunikace a vytvoření prostředí (např. *peer-to-peer, psychologické supervize)* (Hudson et al. 2011), ve kterém se zdravotničtí profesionálové nebojí přiznat chybu (Brattebø, Flaatten 2023).

3.2 Netechnické dovednosti – jejich trénink a hodnocení

Netechnické dovednosti jsou kognitivní, sociální a osobní dovednosti, které doplňují technické dovednosti a přispívají k bezpečnému a efektivnímu plnění úkolů ve zdravotnických systémech. V systému zdravotní péče se stále více ukazuje, že efektivita zdravotnických pracovníků je kombinací technických dovedností, znalostí, etických postojů a netechnických dovedností (non-technical skills / NTS) (Gordon, Darbyshire, Baker 2012). Tyto NTS, bývají členěny na tyto domény (Flin and Maran, 2004a; B. Sharma et al., 2011): komunikaci, týmovou spolupráci, rozhodování a vedení. Navzdory tomu, že NTS hrají zásadní roli v poskytování zdravotních služeb, jsou ve vzdělávání zdravotníků často odsouvány do pozadí a jsou zastíněny důrazem na získávání technických a procedurálních dovedností.

Spokojenost pacientů se zdravotní péčí bývá nejčastěji spočívá v kvalitní a efektivní komunikaci se zdravotníky (Touati et al. 2022). Zvýšený stres vyžaduje precizní komunikaci, zejména pak při klinické práci s vysokým rizikem medicinské chyby jako je v přednemocniční neodkladné péči, na urgentních příjmech či jednotkách intenzivní péče.(Flin and Maran, 2004). Na toto specifické prostředí cílí i tato disertační práce.

Rozvoj NTS u zdravotnických pracovníků vyžaduje inovativní vzdělávací strategie. Jako účinný nástroj se v tomto ohledu ukázal výcvik založený na simulaci, který nabízí bezpečné a kontrolované prostředí s jasně definovanými cíli (Gordon et al. 2015). Prostřednictvím hraní rolí ve vysoce věrných simulacích (*high-fidelity*), či například komunikace ve složitých medicínských situacích (sdělování nepříznivých zpráv a další), si tak mohou účastníci vzdělávání vyzkoušet realistické klinické scénáře, a tím si, kontextově relevantním způsobem, zlepšit své NTS. Toto zážitkové učení je doplněno inter-profesním vzděláváním, které podporuje týmovou spolupráci a komunikaci mezi různými zdravotnickými profesionály (lékaři, sestry, záchranáři, fyzioterapeuti).

Okruhy NTS hodnocené verifikovanými škálami jsou nejčastěji:

- **Vedení a organizace:** zaměřuje se na hodnocení vedoucího týmu, jeho komunikaci směrem k dalším členům, rozdělení úkolů, kontrolu jejich realizace a pozici autority.
- **Spolupráce a týmová práce**: rozložení úkolů mezi členy týmu, jejich načasování, předání informaci o jejich průběhu, dále pak řešení konfliktů, či názorových rozporů, porozumění potřebám týmu, podpora týmu a v neposlední řadě plánování.

- **Řešení úkolů:** zhodnocení rizik a práce s nimi, hledání alternativních možností, zhodnocení dokončení úkolu.
- **Situační povědomí:** sdílení informací, kontrola změn situace, pochopení kapacity povědomí, anticipace dalších akcí.

Hodnocení NTS představuje náročnou oblast, závislou na kontextu a subjektivním vnímáni hodnotitelů. Obecně bylo vyvinuto a validováno několik takových hodnotících škál pro hodnocení NTS ve zdravotnických zařízeních a přednemocniční péči lze uvést následující hodnotící škály:

- TEAM (Team Emergency Assessment Measurement) (Cooper et al. 2010a)
- ANTS (Anaesthetists' Non-Technical Skills) (Flin et al. 2010)
- NOTECHS (Non-Technical Skills for Pilots adapted for Healthcare) (Flin, Maran 2004b)

4 Vzdělávací programy a didaktika

4.1 Implementace simulace do vzdělávání zdravotníků

Za posledních 30 let se celosvětově rozšířila simulační centra pro vzdělávání zdravotníků. V České republice tento rozvoj zaznamenáváme v posledním desetiletí. Jedná se o programy vybudování infrastruktury vzdělávacích center, a s tím spojených samotných simulačních programů a výuky lektorů simulační medicíny (tzv. *train-the-trainer* programy). Simulační medicína je dominantně navázána na na lékařské a zdravotnické fakulty, zdravotnické záchranné služby. Simulační workshopy či kurzy se dostávají do povědomí odborných společností. V současné době je již obsahem specializačního vzdělávání v rámci oboru Anesteziologie a intenzivní medicína povinný 16hodinový simulační trénink (Věstník 2019, Podle zákona č. 95/2004 Sb.). V zahraniční však vidíme trend k pravidelnému a systematickému simulačního tréninku v průběhu celého profesního života.

4.2 Simulace na půdě 3. lékařské fakulty Univerzity Karlovy

V rámci pregraduálního vzdělávání se podařilo na 3. LF UK formovat simulační výuku již od prvního ročníku všeobecného lékařství, kdy si studenti mohou ve věrných simulacích osvojit základy první pomoci. Tento kurz je v současné podobě povinný od roku 2019 pro všechny studenty oboru všeobecné lékařství a všeobecná sestra, a to v českém i anglickém kurikulu. K tomuto kurzu je vytvořen program vzdělávání lektorů a pomocných maskérů (volitelný předmět pro 2. a 3. ročník). Tyto předměty a vzdělávání tak budují unikátní peer to peer model, kdy se studenti vyučují navzájem.

Předmětem, ve kterém byla simulační výuka nejvíce implementována jsou „Neodkladné stavy v resuscitační péči". Tento předmět je dlouhodobě nejlépe hodnoceným předmětem 5. ročníku všeobecného lékařství. Zde je aplikován model obrácené třídy (Morgan et al. 2015), kdy mají studenti předem určené materiály ke samostudiu. Dále musí vyplňovat průběžné testy před jednotlivými výukovými jednotkami. Tento model slouží k tomu, že za poměrně krátkou dobu (1 týden), jsou studenti schopni vstřebat velké množství zkušeností především v simulacích a také např. ve skupinových projektech. Závěrem studenty prověřuje zkouška ve formátu OSCE *(Objective Clinical Skill Examination)*, kde studenti prochází teoretickými testy, komentovanou kazuistikou a zkouškovým simulačním scénářem. Je však třeba poznamenat, že tento způsob výuky založený na simulaci a OSCE zkoušení je velmi personálně náročné.

Simulační centrum 3.LF UK je v současné době využívané i pro postgraduální a specializační výuku. Probíhají zde pravidelná školení Kliniky anesteziologie a resuscitace či Urgentního příjmu Fakultní nemocnice Královské Vinohrady. V rámci specializačního vzdělávání je realizován kurz Simulace kritických stavů oboru Anesteziologie a intenzivní medicína.

4.3 Simulace a zdravotnické záchranné služby v ČR

V České republice dle současné legislativy (Zákon č. *374/2011 Sb., o zdravotnické záchranné službě*) je nutné v rámci jednotlivých krajských organizací zdravotnických záchranných služeb mít zřízeno vzdělávací a výcvikové středisko, které zajišťuje průběžné a kontinuální vzdělávání zaměstnanců v klinickém provozu přednemocniční neodkladné péče (PNP). Recentní dramatický rozvoj simulační medicíny v PNP byl podpořen Evropskými dotacemi z integrovaných regionálních operačních programů.

4.4 Simulace v rámci certifikovaných kurzů

V České republice existují certifikované kurzy garantované českými i zahraničními odbornými společnostmi. Tyto kurzy byly adaptovány v českém prostředí dle doporučení Evropské resuscitační rady. Systém tohoto vzdělávání je stupňovitý. Na začátku stojí účastník, který si může vybrat z palety kurzů resuscitace, péče o dětské pacienty nebo noborozence. Dále tato organizace zastřešuje výběr (instructor potential) a vzdělávání lektorů (instructor candidate) pro tyto kurzu a má vnitřní struktury, spojenou s organizací a určenímvedoucích kurzů (course director). Dále je možné na v České republice absolvovat certifikované kurzy, které nepocházejí z Evropy (PHTLS – Prehospital Trauma Life Support a Advanced Trauma Life Support a další). Základem těchto kurzů je strukturovaná výuka, simulační přístupy a bezprostřední praktické využití nejen lékaři, ale také zdravotnickými záchranáři a dalšími zdravotníky.

Další možností, jak se zapojit do simulační výuky, jsou kurzy pořádané Ústavem simulační medicíny Lékařské fakulty Masarykovy Univerzity. Tyto kurzy jsou realizovány v rámci simulačního centra SIMU v Brně, které je jedním z největších na světě. Zde je paleta kurzu velmi široká – přednemocniční péče, ošetřovatelská péče, či konkrétní lékařské dovednosti. Ostatní lékařské a zdravotnické fakulty napříč Českou republikou vyvíjí snahu nabídnout alespoň část z výše zmíněného.

4.5 Budoucí směry a výzvy simulační medicíny

Zdokonalování metodik hodnocení a zvyšování relevance a spolehlivosti hodnotících škál a postupů je stále vyvíjející se oblast simulace v medicíně (Ayaz, Ismail 2022). V současné době lze v simulační medicíně extenzivně využívat moderní informační technologie vč. umělé inteligence prakticky ve všech oblastech od tvorby výukových materiálů, ovládání scénářů až po testování znalostí (Park, Tiefenbach, Demetriades 2022; Winkler-Schwartz et al. 2019).

Širší zavádění simulací brzdí vysoké pořizovací a provozní náklady i personální náročnost (Maloney, Haines 2016). Navíc pro lektory, této personálně náročné disciplíny, je nutné trvale zajišťovat průběžné vzdělávání (*train-the-trainers* programy), tak abychom zajistili standardizovanou a strukturovanou a up-to-date výuku.

Kromě ekonomických, technických a personálních aspektů přetrvává výzva v podobě správného zařazení medicinské simulace do širšího a správně zmapovaného kurikula vzdělávání zdravotnických profesionálů, aby simulace byla jako pedagogický nástroj maximálně didakticky účinná. (Ahmed et al. 2022).

5 Komentář ke studii – Vliv osobních ochranných pomůcek v simulované krizi

5.1 Pozadí studie

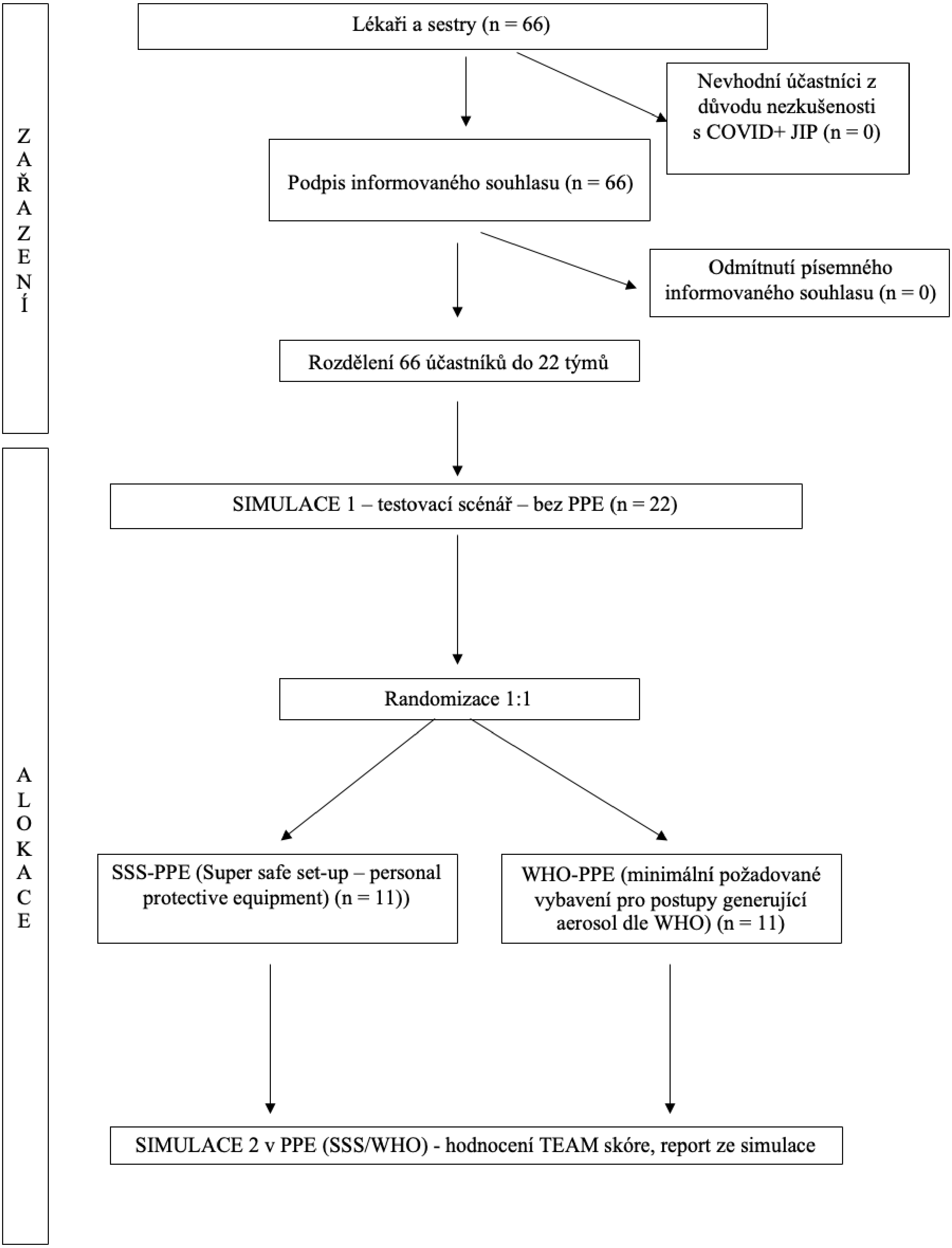
V počátku pandemie onemocnění virem COVID-19 nebylo zřejmé, jak může být infekce závažná. Z tohoto důvodu panovaly pochybnosti o nezbytné míře stupně používaných osobních ochranných pracovních pomůcek (Personal Protective Equipment / PPE). V praxi dle tehdejšího doporučení Státního zdravotního ústavu (SZÚ) byla míra PPE, zejména na jednotkách intenzivní péče významně přísnější než standard dle Světové zdravotnické organizace (WHO) pro aerosoly šířící se onemocnění. Doporučení SZÚ pramenilo z nejistoty o povaze a chování viru v začátku pandemie (‘Bezpečné používání osobních ochranných prostředků (OOP) při poskytování lůžkové zdravotní péče pacientům s COVID-19’, 2020). Toto nastavení (celotělový oblek, tři vrstvy rukavic, respirátor FFP3 a obličejový štít) však může být velmi fyzicky i psychicky zatěžující (Tabah et al., 2020; Galanis et al., 2021). Manuální zručnost zdravotníků mohla být kvůli těmto pomůckám snížena (Ruskin et al. 2021; Jen et al. 2021a). Naproti tomu standard Světové zdravotnické organizace (WHO) (Technical specifications of personal protective equipment for COVID-19, 2020) osobních ochranných pomůcek pro aerosoly generující procesy byl významně redukovaný oproti běžně užívanému standardu. Obsahoval respirátor, plášť, jednu vrstvu rukavic a osobní obličejový štít (podrobný popis viz Příloha 1). Tento standard byl v České republice až následně doporučován Státním zdravotním ústavem a přijat do klinické praxe.

Cílem studie bylo zhodnocení vlivu těchto dvou úrovní nastavení PPE na simulovanou krizovou situaci. Hodnocení probíhalo ve třech hlavních oblastech – netechnické dovednosti, kvalita resuscitace a fyziologické funkce účastníků.

5.2 Metodika

Jednalo se o simulační, randomizovanou studii. Do studie bylo rekrutováno celkem 22 lékařů a 44 sester. Tým se vždy skládal z jednoho lékaře a dvou sester, náhodně přiřazených do týmu. Všichni účastníci studie měli praxi spojenou s péčí o pacienty s COVID-19 a pracovní zkušenost na jednotkách intenzivní péče – JIP (*Intensive Care Unit/ ICU*). Účastníci prošli základním testovacím scénářem bez osobních ochranných pomůcek, kde si vyzkoušeli simulované prostředí, seznámili se simulátorem a naučili se používat dostupné vybavení.

Trojčlenné týmy účastníků byly randomizovány v poměru 1:1 do dvou skupin SSS-PPE (Super Safe Set-up) (n = 11) a WHO-PPE (World Health Organization Set-up) (n = 11). Před a po simulaci byly měřeny vitální hodnoty všech účastníků. Samotná simulace měla technikem řízený scénář. Tématem scénáře byla hypoxická náhlá zástava oběhu u pacienta po dislokaci endotracheální kanyly. Scénář trval 10 minut a jeho průběh nebyl variabilní. Během simulace bylo hodnotitelem vyplněno TEAM skóre (Team Emergency Assessment Measurement). Po simulaci bylo doplněno souhrnné subjektivní hodnocení účastníků týmu (viz Příloha 1).



Obr. 1 Vliv osobních ochranných pomůcek v simulované krizi – study-flow diagram.

Měření:

- Netechnické dovednosti (NTS)

Primárním výsledkem byla výkonnost týmu hodnocená pomocí TEAM skóre (viz metodika studie popsaná v Suplementary data Přílohy 1). Jedná se o validovanou stupnici, na které hodnotitel uděluje od 0 (nikdy nepozorováno) do 4 (pozorováno vždy) bodů v každém z 11 parametrů, které popisují postoje, postupy a chování týmu (Cooper et al. 2010b). Následně bylo uděleno globální skóre (1 – 10 bodů) a doplněno sečtené skóre z jednotlivých položek jako tzv. total score. Detailní popis skórovacího systému je uvedeno v příloze č. 1. Všechna bodová hodnocení prováděl vždy proškolený pozorovatel, seznámený s tímto hodnocením a u 4 náhodně vybraných scénářů byla ověřena nízká variabilita mezi hodnotiteli (Posner et al. 1990).

- Kvalita a průběh KPR

Sekundárními výsledky byly objektivní ukazatele kvality a časového průběhu KPR. Index celkové kvality resuscitace (%) analyzovaný simulačním softwarem Laerdal (LLEAP, 2014, verze 7.3.0/zimní 2021). Samostatně byly hodnoceny jednotlivé časy provedení výkonů během KPR: rozpoznání zástavy (čas od zástavy oběhu do první komprese hrudníku), čas do první efektivní ventilace, čas do zajištění dýchacích cest (umístění endotracheální kanyly) a doba do podání prvního adrenalinu.

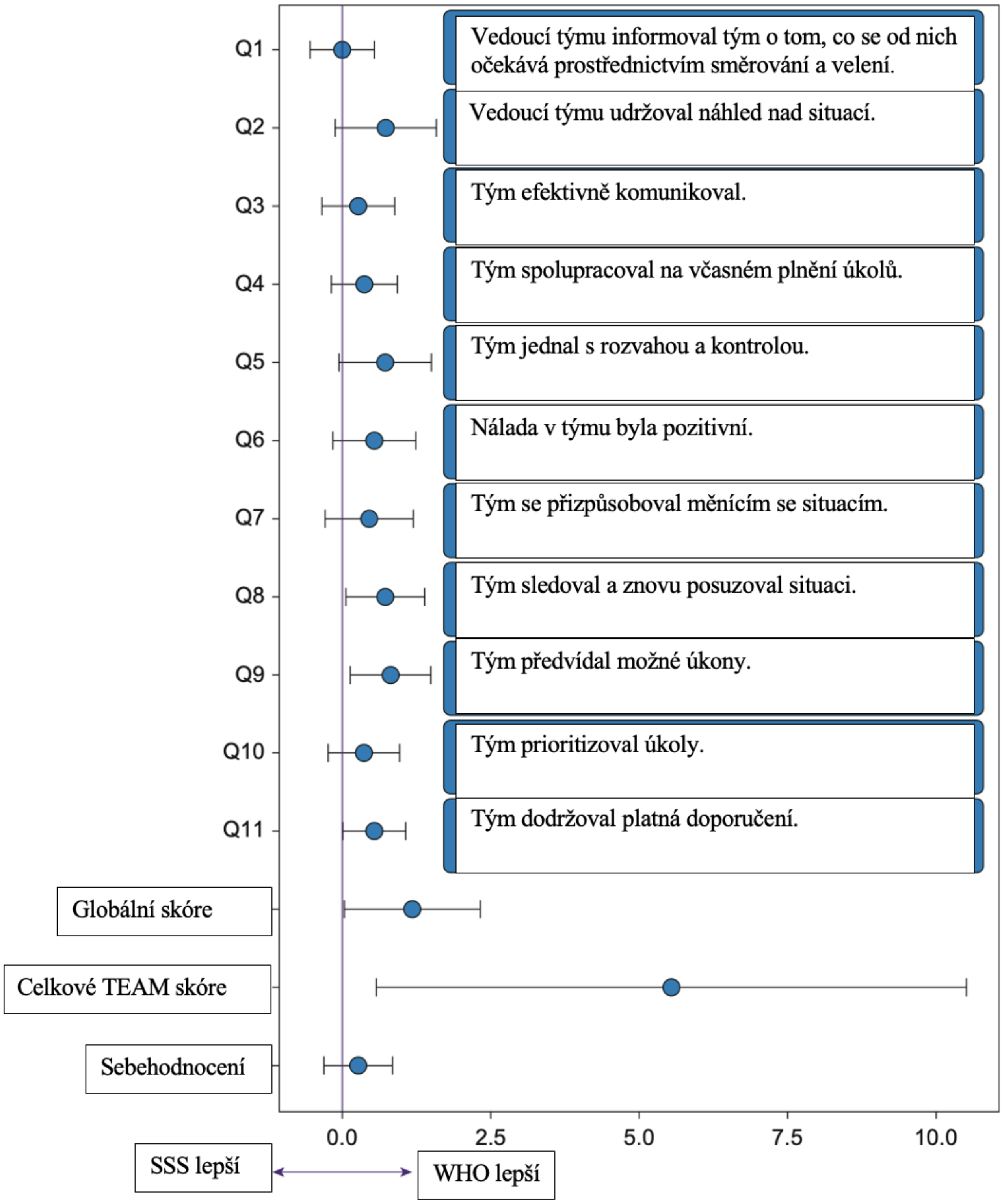
- Fyziologické hodnoty účastníků

Byly měřeny změny fyziologických hodnot členů resuscitačního týmu: saturace kyslíkem (SpO2%), srdeční frekvence (TF/min) a tělesné teploty u zachránců (°C). Kompletní detaily měření jsou uvedené v Příloze 1.

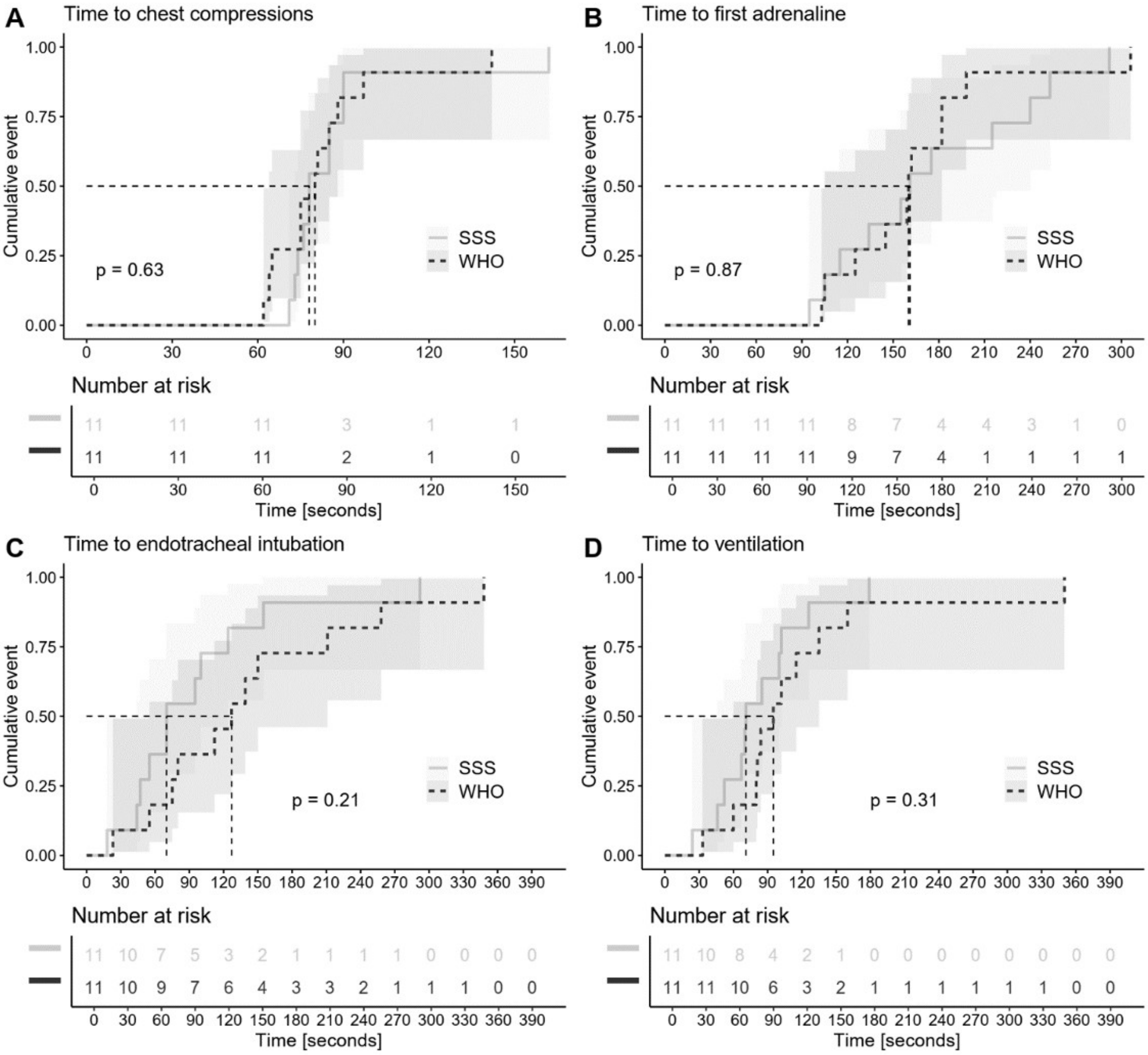
5.3 Výsledky

Extendované osobní ochranné prostředky (SSS-PPE) nad rámec standardních doporučení dle WHO (WHO-PPE) vedly k celkově horšímu výkonu v rámci NTS během simulované krize v intenzivní péči (viz obr. 2 - *Výsledky TEAM skóre u PPE (Personal Protective Equipment) studie)*.

Navzdory zhoršení týmové dynamiky nebyly zjištěny žádné významné rozdíly v rozpoznání srdeční zástavy nebo parametrech kvality KPR (viz obr. 3 - *Kaplan-Meierovy křivky technického provedení KPR v simulované krizi*). Fyziologické hodnoty zachránců nebyly ovlivněny využitím PPE.



Obr. 2 Výsledky TEAM skóre u PPE studie.



Obr. 3 Kaplan-Meierovy křivky technického provedení KPR v simulované krizi (anglicky).

5.4 Diskuse

V této prospektivní randomizované studii byl pozorován vliv vyššího stupně PPE (SSS) na zhoršení NTS především kvůli horšímu výkonu ve složitých úkolech, jako je přehodnocení situace a předvídání možných akcí. Vyšší stupeň PPE již neměl dopad na kvantitativní parametry kvality prováděné KPR, ani na fyziologické funkce zachránců.

Scénáře náhlé zástavy oběhu jsou obvykle dobře nacvičené, s jasnými kroky dle doporučení (Soar et al. 2021). Tento fakt mohl zmírnit negativní účinky navyšování stupně osobních ochranných prostředků na výkon týmu, což mohlo zachytit skóre TEAM (Cooper et al. 2010a). Skóre TEAM, navržené pro hodnocení netechnických dovedností týmů, pravděpodobně odráželo komunikační problémy, které představuje používání respirátorů, chirurgických masek a obličejových štítů. Tyto pomůcky mohou bránit verbální a neverbální interakci. Týmy ovšem mohou tyto překážky kompenzovat zvýšeným soustředěním a pozorností.

Spory ohledně vlivu osobních ochranných pomůcek na objektivní ukazatele kvality a zručnost zůstávají v literatuře nevyřešeny (Hillinger et al. 2024). Některé studie poukazují na zhoršení podmínek pro manuální dovednosti (Jen et al. 2021b). Jiné studie rozdíl v kvalitě KPR nezjistily (Cui, Jiang; Rauch et al. 2021).

Plošná doporučení dle modifikovaných pokynů Evropské rady pro resuscitaci pro pacienty s podezřením nebo s potvrzeným onemocněním COVID (*European Resuscitation Council COVID-19 Guidelines* 2020) usilují o vyvážení bezpečnosti a účinnosti během resuscitace. Zdůrazňují ochranu zachránců, zejména během postupů vytvářejících aerosol (zajištění dýchacích cest, komprese hrudníku a další).

Studie nezjistila rozdíly ve fyziologických hodnotách u zdravotnických pracovníků v tomto krátkodobém kontextu. Sestry na jednotkách intenzivní péče obvykle pracovaly v delších směnách, a přitom používaly osobní ochranné prostředky. Je pravděpodobné, že navyšování míry osobní ochranné prostředků by tak mohlo představovat zátěž, která by mohla zvýšit únavu, ovlivnit individuální výkonnost a dále netechnické dovednosti v kontextu déletrvající pracovní zátěže.

5.5 Závěr

Za využití simulační medicíny bylo zjištěno, že vyšší stupeň PPE vede ke zhoršení NTS během simulované krize. Vyšší stupeň PPE nevede při extendovaných osobních prostředcích ke zhoršení celkové kvality kardiopulmonální resuscitace.

6 Komentář ke studii – Podávání sufentanilu nelékařskými zdravotnickými pracovníky bez konzultace lékaře

6.1 Pozadí studie

Kvalitní a bezpečná léčba bolesti je standardem (Visser et al. 2017), který je zvláště důležitý v rámci PNP poskytované zdravotnickými záchrannými službami (ZZS). Vzdělávání zdravotníků založené na CBME přímo souvisí s účinností a efektivitou poskytování PNP. V České republice, podobně jako v mnoha evropských zemích, se systém PNP historicky opírá o lékaře, což je praxe hluboce zakořeněná v tradičních franko-německých modelech zdravotní péče (Timmermann, Russo and Hollmann, 2008; Seblova et al., 2018). Kompetence výjezdových skupin zdravotnických záchranářů bez lékaře, které tvoří obecně ústřední pracovní článek ZZS, jsou však definovány právními normami a ve světě se značně liší (Wilson et al. 2015).

V rámci české ZZS nemají zdravotničtí záchranáři tradičně oprávnění podávat analgetickou medikaci samostatně, bez přímého dohledu nebo telefonického vedení lékaře ZZS. Toto ustanovení, dané zdravotnickou legislativou (55/2011 Sb. Vyhláška o činnostech zdravotnických pracovníků a jiných odborných pracovníků), se stává stále tíživějším kvůli stupňujícímu se nedostatku lékařů v přednemocniční péči, který je způsoben personálními a ekonomickými omezeními. V důsledku toho dochází k emergentnímu posunu směrem ke zvyšování a rozšiřování kompetencí zdravotnických záchranářů. K těmto podmínkám přispívá právní ustanovení umožňující organizacím delegovat na zdravotnické záchranáře konkrétní pravomoci v rámci standardních pracovních protokolů pro rutinní postupy v přesně vymezených situacích.

Cíle této studie bylo vytvořit standardizovaný a vysoce protokolizovaný postup pro zdravotnické záchranáře a ověřit jeho použití a bezpečnost.

6.2 Metodika

Úvodní průzkum zaměřený na léčbu akutní bolesti související s úrazem byl proveden dotazníkovým šetřením mezi záchranáři Zdravotnické záchranné služby Karlovarského kraje. Šetření přineslo vysokou míru návratnosti odpovědí (81 %, odpovědělo 95 ze 115 účastníků). Poznatky z průzkumu ukázaly, že významná většina zdravotnických záchranářů (80 %, n = 76) považuje za zásadní mít kompetence k podání sufentanilu v nepřítomnosti lékaře. Pro nácvik bylo nutné připravit simulační kurz, kde zdravotničtí záchranáři mohli trénovat praktické použití sufentanilu v protokolární indikaci. V reakci na výše zmíněný průzkum byl vytvořen dobrovolný školící program, kterého se následně rozhodlo zúčastnit 39 zdravotníků. Tento kurz dokončili všichni přihlášení účastníci.

U účastníků byly zaznamenány demografické údaje, věk a pohlaví, profesní zkušenosti a vzdělání, které bylo rozlišeno podle úrovně vysokoškolského nebo vyššího odborného. Přípravná fáze programu zahrnovala e-learningový modul zaměřený na farmakologické vlastnosti sufentanilu, jeho klinické použití a specifická indikační kritéria. Dále bylo detailně vysvětleno použití v případech akutního traumatu u dospělého pacienta, oběhově stabilního a zcela při vědomí (definice viz příloha č.2). Samotný kurz spočíval ve čtyřhodinovém praktickém výcviku metodami simulační medicíny. Simulace byly navrženy tak, aby odrážely scénáře z reálného klinického provozu. Zdůrazňovaly důležitost správného dávkování léku, identifikaci akutní traumatické bolesti u dospělých. Důležité bylo rozpoznání a zvládání potenciálních nežádoucích účinků, zejména útlumu dechu. Na základě těchto kritérií mohli záchranáři s přidělenou kompetencí protokolárně podávat sufentanil. Účastníci byli vyškoleni v titraci intravenózně podávaného sufentanilu postupně po 5 mikrogramech, přičemž maximální přípustná intravenózní dávka v rámci jejich kompetencí byla omezena na 20 mikrogramů. Závěrečné hodnocení kompetencí zdravotníků zahrnovalo komplexní hodnocení trojicí lékařů – anesteziologů působících na ZZS. Toto hodnocení zahrnovalo šest simulovaných akutních situací, praktickou zkoušku techniky ventilace pomocí samorozpínacího vaku a obličejové masky. Nakonec složením písemné zkoušku zaměřené na ověření znalostí o vedlejších účincích, vhodných indikačních kritériích a dávkování při podávání sufentanilu.

Následně proběhla analýza v šestiměsíčním období v reálném provozu. Analýza srovnávala atributy a bezpečnost podání sufentanilu záchranáři s kompetencí k jeho podání (skupina Kompetence). Tato skupina byla porovnána se skupinou, kdy byl sufentanil podán u případů akutního traumatu záchranářem na místě (bez kompetence k podání sufentanilu) po telefonické konzultaci s indikujícím lékařem (skupina Konzultace). Sledovány byly hlavně nežádoucí účinky a jejich řešení. Dále byl sledován efekt analgetické terapie, a to pomocí redukce bodového ohodnocení na škále bolesti *Numeric Rating Scale* (NRS).

6.3 Výsledky

Během studijního období podali záchranáři samostatně intravenózně sufentanil 70 pacientům s akutním traumatem (skupina Kompetence) a po telefonické konzultaci s lékařem 88 pacientům ZZS (skupina Konzultace). . Průměrná dávka podaného sufentanilu byla v obou skupinách srovnatelná (viz tab. č. 1).

Z hlediska hlášení výskytu nežádoucích účinků nebyla u žádné ze studijních skupin hlášena zástava dechu nebo bradypnoe, stejně jako potřeba kyslíkové terapie po podání sufentanilu. Výskyt nevolnosti byl v obou skupinách stejný. Intravenózní antiemetika byla použita méně často v konzultační skupině (viz tab. č. 3). V obou skupinách došlo ke snížení bolesti v NRS bez statisticky významného rozdílu mezi skupinami (viz tab. č. 2).

Podávání opioidů zdravotnickým záchranářem nemělo statistický ani klinický vliv na systolický a diastolický krevní tlak, srdeční frekvenci, periferní saturaci kyslíkem a dechovou aktivitu.

	KONZULTACE (n = 88)	KOMPETENCE (n = 70)	
Věk (roky)	64,6 (19,7)	65,7 (20,0)	NS
Pohlaví (ženy)	61 (69 %)	39 (56 %)	NS
NACA skóre	2,5 (0,5)	2,4 (0,5)	NS
Trauma dolní končetiny	57 (65 %)	35 (50 %)	
Trauma horní končetiny	23 (26 %)	22 (31 %)	NS
Trauma trupu	8 (9 %)	13 (19 %)	
Trauma hlavy	0	0	NS
Dávka sufentanilu (µg)	9,1 (2,0)	9,4 (2,4)	NS
Frakcionované podání	24 (27 %)	20 (29 %)	NS
Přidáno neopioidní analgetikum	12 (14 %)	10 (13 %)	NS

Tab. 1 Výsledky Studie Sufenta – základní charakteristika skupin, NS – nesignifikantní

	KONZULTACE (n = 88)	KOMPETENCE (n = 70)	
Kompletní report NRS	23 (26 %)	60 (86 %)	P <0.05
NRS redukce (počet bodů)	-3.2 (1.2)	-3.9 (1.8)	NS
Iniciální NRS (počet bodů)	6.4 (1.5)	7.9 (1.4)	P <0.05

Tab. 2 Výsledky reportování NRS (numeric rating scale) mezi skupinami KONZULTACE vs. KOMPETENCE (data jsou prezentována jako počet (procento) nebo průměr (směrodatná odchylka).

	KONZULTACE (n = 88)	KOMPETENCE (n = 70)	
Zástava dechu	0	0	NS
Bradypnoe	0	0	NS
Oxygenoterapie po podání sufentanilu	0	0	
Nauzea	3 (3 %)	2 (3 %)	NS
Zvracení	0	4 (6 %)	NS
Podání antiemetik	1 (1 %)	5 (7 %)	P <0,05

Tab. 3 Výsledky výskytu nežádoucích událostí mezi skupinami KONZULTACE vs. KOMPETENCE

6.4 Diskuse

Tato studie potvrdila proveditelnost a bezpečnost přidělování nových kompetencí na základě simulačního výcviku spojeného s důsledným ověřováním znalostí a dovedností. Zjištěné nežádoucí účinky byly minimální, pravděpodobně z důvodu přísných kritérií stanovených pro podání sufentanilu.

Snížení potřeby telefonických konzultací potenciálně snižuje pracovní zátěž zdravotníků i lékařů. Školení zdravotnických záchranářů pro zvládání možných komplikací po podání sufentanilu má širší dopad. Tato možnost zvyšuje celkové kompetence záchranáře a připravenost na situace, kdy lékař ordinuje na dálku a nemůže se vzniklým komplikacím věnovat na místě události.

Limitace studie spočívala v dobrovolné povaze účasti záchranářů, monocentrickém charakteru a observační povaze studie. Studie byla provedena v relativně krátkém období během pandemie COVID-19. Toto období bylo charakteristické snížením počtu úrazů v důsledku karanténních opatření a omezeného pohybu obyvatelstva. Za zmínku stojí rozpory ve vykazování numerické hodnotící škály (NRS) mezi skupinami. Vyškolení záchranáři museli dodržovat nový standard péče, který při zvažování podání opioidů nařizoval hlášení NRS, což mohlo být příčinou rozdílů v důkladnosti hlášení mezi skupinami.

Tato studie dokládá, že navýšení kompetencí event. rozšíření protokolárního řešení situací může u zdravotnických záchranářů zvýšit kvalitu a bezpečnost péče tím, že podpoří větší odpovědnost a motivaci záchranářů. Nutné je však vždy odlišovat přidělení kompetence v celé své šíři a protokolární podávání léčiv pro velmi pečlivě definovanou skupinu pacientů.

Podávání opioidů k léčbě bolesti v urgentní medicíně, zejména v PNP, zůstává neustále rozvíjející se oblastí (Pietsch et al. 2021; Niemi-Murola, Unkuri, Hamunen 2011). Tato studie je originální zaměřením na intravenózní podávání sufentanilu záchranáři bez dohledu lékaře, přispívá k rostoucímu počtu výzkumů zkoumajících různé opioidy a metody jejich podávání. Ačkoli se nezabývá péčí o děti nebo jinými zdravotními obtížemi, je v souladu se studiemi z podobných zdravotnických systémů, které obhajují svěření přednemocniční analgezie vyškoleným zdravotníkům – záchranářům (Häske et al., 2017).

Přijetí principů CBME by mohlo zdravotnickým záchranářům umožnit dále získat potřebné dovednosti a kompetence, a tím zlepšit kvalitu péče a zajistit včasnou a účinnou léčbu bolesti v přednemocničním prostředí (Wedmore et al. 2012; Pietsch et al. 2021). Přístup CBME dává důraz na systematický a strukturovaný režim vzdělávání. Je důležitý důraz na vzdělávání založeném na simulacích, který má tyto kritické kompetence budovat, hodnotit a zajistit, aby zdravotničtí záchranáři byli dobře vybaveni k poskytování péče, zmírňování rizik a samostatnému řešení komplikací, a tím se zvýšila celková účinnost a efektivita zdravotnické záchranné služby.

6.5 Závěr

U dospělých pacientů s bolestí při akutním traumatu ve specifikovaném klinickém stavu prokázalo samostatné podání intravenózního sufentanilu zdravotnickými záchranáři s příslušnou kompetencí srovnatelnou analgetickou účinnost i bezpečnost jako podání po telefonické konzultaci s lékařem. Tato intervence byla spojena s dostatečným analgetickým efektem a nízkým výskytem nežádoucích účinků.

7 Komentář ke studii – Netechnické dovednosti v přednemocniční péči

7.1 Pozadí studie

Ke zlepšení výsledků kardiopulmonální resuscitace (KPR) se využívá výcvik netechnických dovedností (NTS) (Perkins et al., 2021), včetně výcviku vedení a týmové práce (Greif et al. 2021). Popis NTS zahrnuje několik klíčových složek viz výše kapitola 3.2. a v podkapitole 7.2. Publikovaných studií o použití NTS v reálném zdravotnickém prostředí je nedostatek, ve skutečném nesimulovaném prostředí PNP chybí úplně.

Hlavním cílem této studie bylo zjistit a popsat, zda a jak jsou v České republice uplatňovány NTS při poskytování PNP při přítomnosti alespoň dvou výjezdových skupin na místě. Sekundárním cílem bylo porovnat, zda se používání NTS a výkonnost týmů liší podle typu události, jako je provádění kardiopulmonální resuscitace, u traumatu nebo obecných zdravotních obtíží.

7.2 Metodika

Byla provedena prospektivní, observační multicentrická studie NTS v klinických přednemocničních urgentních stavech. Nebyla použita žádná randomizace. Výzkum probíhal na třech zdravotnických záchranných službách České republiky: ZZS Hlavního města Prahy, ZZS Karlovarského kraje a ZZS Plzeňského kraje. Tyto kraje mají celkem 2,2 milionu obyvatel a ročně zde ZZS řeší 250 000 akutních zásahů. Sběr dat probíhal od října 2019 do srpna 2020. Zařazeny byly všechny události ZZS, na kterých se v rámci přednemocniční péče podílely dva a více týmů (tedy PNP byla poskytována nejméně čtyřmi zdravotníky – členy výjezdových skupiny). V terénu na rozdíl od práce např. na *emergency* zdravotnického zařízení není prakticky možné provádět sledování NTS, proto byl využíván tzv. inspektor provozu těchto ZZS. Systém ZZS je v těchto krajích strukturován jako model rendez-vous, kdy v sanitních vozech (RZP) pracují zdravotničtí záchranáři a ve vozech (RV) zdravotničtí záchranáři a lékař. Tyto výjezdové skupiny jsou ve všech třech regionech podporovány a kontrolovány inspektory provozu. Vyloučeny byly výjezdy, které se týkaly pouze jedné (dvoučlenné) výjezdové skupiny, pokud pro událost nebyl dostupný inspektor provozu nebo chyběl kompletní záznam o výjezdu.

Ve studii byla použita upravená a zjednodušená verze TEAM skóre (Team Emergency Assessment Measure). Validace původního nástroje je zdokumentována jinde a nebyla součástí této studie (Cooper et al. 2010b). Úprava zahrnovala zachování prvních šesti položek beze změny: (1) vedoucí týmu sděloval očekávání prostřednictvím pokynů a příkazů, (2) vedoucí týmu si udržoval celkový nadhled, (3) efektivní komunikace v týmu, (4) včasné dokončení úkolů, (5) klid a kontrola týmu a (6) pozitivní morálka týmu. Položky 7 (přizpůsobování se měnícím se situacím) a 8 (sledování a přehodnocování situace) byly sloučeny, stejně jako položky 9 (předvídání možných akcí) a 10 (stanovení priorit úkolů). Položky 11 (dodržování schválených standardů) a 12 (celkové hodnocení) byly vynechány, aby bylo zjednodušeno hodnocení pro inspektory provozu v reálném běhu poskytování PNP a ta nebyla nikterak ohrožena.

Tato upravená verze byla již dříve použita k hodnocení NTS v simulovaných scénářích a byla výzkumníkům i vedoucím v terénu známá (Peřan et al. 2017). Každá z osmi položek TEAM byla hodnocena na pětibodové škále (0 nikdy, 1 zřídka, 2 někdy, 3 často, 4 vždy) a zahrnovala vedení, týmovou práci a řízení úkolů. Pro další statistickou analýzu bylo použito celkové skóre, tedy součet těchto hodnocení.

Dvacet inspektorů provozu (ZZS HMP, n = 5; ZZS KVK, n = 6; ZZS PK, n = 9) absolvovalo před zahájením studie standardizovaný e-learningový kurz o používání modifikovaného skóre TEAM. Hodnotili videozáznamy dvou simulovaných klinických scénářů pro posouzení nízké míry variability hodnocení mezi jednotlivými hodnotiteli.

Studie dále porovnávala výsledky pozorování ve třech podskupinách klinických situací (výjezdů ZZS):

1. kardiopulmonální resuscitace (KPR – probíhající resuscitace v důsledku mimonemocniční zástavy oběhu),
2. traumatické události (TRAUMA – jakékoliv zranění)
3. a obecné netraumatické události (MEDICAL – netraumatické situace, které nesouvisejí s KPR, včetně pediatrických výjezdů).

Organizace	ZZS hl. m. Prahy	ZZS Karlovarského kraje	ZZS Plzeňského kraje
Sledované události (n)	162	100	100
Vyřazená hodnocení (n)	2	0	1
Hodnocení zařazená do další analýzy (n)	160	100	99
Celkem analyzováno (n)	359		

Tab. 4 Netechnické dovednosti v přednemocniční péči – study-flow diagram.

7.3 Výsledky

Ve studii bylo analyzováno celkem 359 výjezdů, po vyloučení tří z důvodu neúplných údajů o výjezdu (viz tab. 4). Typy výjezdů se mezi třemi kraji lišily, jak je shrnuto v tab. 5. Souhrnem byly dle charakteru události hodnoceny tyto tři skupiny (KPR, n=110; TRAUMA, n=122; MEDICAL, n=127). V naprosté většině se jednalo o práci dvou výjezdových skupin s celkem tedy čtyřmi zdravotníky na místě (n=317).

	ZZS hl. m. Prahy (n = 160)	ZZS Karlovarského kraje (n = 100)	ZZS Plzeňského kraje (n = 99)	Celkem (n = 359)
Typ události:				
KPR	72 (45 %)	11 (11 %)	27 (27 %)	110 (31 %)
Trauma	84 (53 %)	8 (8 %)	30 (30 %)	122 (34 %)
Ostatní	4 (2 %)	81 (81 %)	42 (43 %)	127 (35 %)
Počet výjezdových skupin na místě:				
Dvě	142 (88 %)	99 (99 %)	76 (77 %)	317 (88 %)
Tři	12 (8 %)	1 (1 %)	16 (16 %)	29 (8 %)
Více	6 (4 %)	0	7 (7 %)	13 (4 %)

Tab. 5 Charakteristika analyzovaných výjezdů – výsledky. Data jsou vyjádřena jako počet (n) a procenta.

Modifikované skóre TEAM ukázalo vysoké využití a „provádění“ NTS obecně (detailní výsledky v Příloze 3). V žádné konkrétní oblasti dovedností nebyly zaznamenány výrazné nedostatky.

V podskupinách (KPR, Trauma, MEDICAL) byl jediný významný rozdíl v položce 1 (*jasný team leader, tým na základě povelů a příkazů jasně ví, co bude následovat*). Post hoc analýza odhalila, že tento rozdíl je v neprospěch leadershipu u skupiny MEDICAL události oproti skupině KPR. Jiné statisticky významné rozdíly nebyly mezi různými typy výjezdů odhaleny. Přestože u traumat byl trend k horšímu výkonu v položce 4 (*tým pracuje společně, příkazy jsou v týmu vykonávány ve správný okamžik*) a v položce 5 (*tým pracuje v klidu a pod kontrolou*). Detailní výsledky, tabulky a meziskupinová porovnání jsou prezentovány v příloze 3.

7.4 Diskuse

Výsledky prokázaly vysokou míru využití a používání NTS napříč různými zdravotními stavy v reálném prostředí PNP. Předchozí studie ukázaly podobná zjištění, ale v nemocničním prostředí. V rámci simulací byly zaměřeny na specifické aspekty NTS pouze při mimonemocničních událostech srdeční zástavy (Lauridsen et al. 2020; Bennett, Mehmed, Williams 2021; Dewolf et al. 2021). Naše data z reálného klinického prostředí závažných událostí v PNP vyžadující součinnost více výjezdových skupin jsou konzistentní a spolehlivé, srovnatelné s původními studiemi, s pozorovanou a hodnocenou variabilitou mezi jednotlivými hodnotiteli (Posner et al. 1990).

Zpočátku byl pro pilotní pozorování v terénu použit kompletní formulář TEAM (Cooper et al. 2016; Cant et al. 2016). Na základě této pilotní fáze byl však přijat zjednodušený formulář pro terénní analýzu v přednemocniční péči. Na rozdíl od některých studií, které používají videozáznamy, tato studie hodnotila NTS v reálném čase.

Tato studie poskytuje základní poznatky o NTS ve třech různých organizacích ZZS v České republice, včetně městských, venkovských a smíšených regionů. Cílem nebylo hodnotit vliv NTS na klinický výsledek, ale zaměřit se na NTS, které jsou častým objektem simulačního tréninku. Záměrem bylo též vytvořit reprezentativní mix případů PNP, nikoliv porovnávat jednotlivé jednotky ZZS mezi sebou.

Nástroj TEAM byl vybrán pro svou účinnost i při hodnocení traumatu. Většina studií uvádí průměrné nebo mediánové skóre TEAM kolem 3 (ze škály položek 0-4). V této studii nebyly použity další nástroje hodnocení NTS, jako je škála netechnických dovedností pro trauma (T-NOTECHS), aby byla zachována konzistence s jedním hodnotícím nástrojem.

Limitacemi by mohlo být úprava TEAM skóre pro tuto studii. Některé položky byly sloučeny a celkové skóre bylo vypuštěno, aby se zjednodušilo hodnocení a zaměřilo se na konkrétní aspekty NTS v dynamickém klinickém prostředí. TEAM je osvědčená metoda, proto byla před statistickou analýzou kontrolována pouze konzistence údajů. Přestože bylo v terénu 20 supervizorů (inspektorů provozu), jejich rozsáhlé školení v hodnocení TEAM zajistilo nízkou variabilitu mezi hodnotiteli. Dalším limitací mohlo být zahrnutí pediatrických události do obecné skupiny MEDICAL. Díky čistě popisnému charakteru studie a bez sledované intervence byl předem stanoven pro reálné prostředí ambiciózní cíl zařadit 100 měření z každé ZZS.

7.5 Závěr

Celková úroveň netechnických dovedností (NTS) ve sledované skupině přednemocniční neodkladné péče byla v této studii hodnocena jako velmi dobrá. Výsledky jsou pozitivní, avšak je třeba je vnímat jako předběžné. Zdůrazňují potřebu dalšího výzkumu zaměřeného na netechnické dovednosti, jejich vliv na klinické výsledky a efekt simulačního vzdělávání. Skórovací systém TEAM se ukazuje jako vhodný nástroj nejen pro hodnocení a rozvoj výuky NTS v simulovaném prostředí, ale i v reálné klinické praxi, včetně přednemocniční péče.

8 Komentář ke studii – Rozšířená resuscitace dospělých v podání dvoučlenných výjezdových skupin záchranné služby

8.1 Pozadí studie

U mimonemocniční zástavy oběhu (OHCA) včasné zahájení kvalitní rozšířené resuscitace (ALS) zvyšuje šanci na návrat spontánního oběhu (ROSC) a přežití (Kurz et al. 2018). V systémech PNP často poskytují ALS jako první dvoučlenné výjezdové skupiny (Dick 2003). Takto malé týmy však čelí značným obtížím při dodržování doporučeného postupu ALS v počátečních fázích KPR (Brucke et al., 2007). Doporučení Evropské rady pro resuscitaci (ERC) jsou aplikovatelná obvykle u větších týmů, které si mohou rozdělit pracovní zátěž a jednotlivé úkoly.

Algoritmus rozšířené resuscitace rozlišuje priority léčby podle toho, zda má OHCA defibrilovatelný či nedefibrilovatelný rytmus. Pro dvoučlenné týmy vznikají problémy hlavně při zajištění dýchacích cest a podávání léků. V algoritmu ALS je uvedeno více úkolů, proto je nutné stanovení priorit. Důležitost se klade na dodržení kvalitních kompresí hrudníku a dýchání není ve dvou osobách možné provádět komplexnější úkoly současně, tak jak to mohou dělat vícečlenné týmy.

Předchozí studie zkoumaly přizpůsobení algoritmu ALS pro dvoučlenné týmy v letecké záchranné službě (HEMS) a ve vojenském prostředí, navzdory svému významu tak není provádění ALS dvěma záchranáři dobře prozkoumáno.

Cílem této přehledové studie je shrnout a kriticky zhodnotit stávající evidenci a identifikovat témata publikovaného výzkumu ALS poskytovaného dvoučlennými výjezdovými skupinami.

8.2 Metodika

Toto scoping review je zpracováno podle metodiky Joanna Briggs Institute (Pearson et al., 2005; Peters et al., 2015) pro přehledové studie dle doporučené struktury PRISMA-ScR (Tricco et al. 2018). Cíle, kritéria zařazení a metody byly předem definovány v protokolu, který byl společně revidován akademickým výzkumným týmem a zaregistrován v databázi Open Science Framework dne 1. září 2023.

Do review byly zahrnuty studie publikované od 1. ledna 2005 do 30. listopadu 2023. Toto období pokrývá doporučení, která zavedly poměr kompresí hrudníku a záchranných vdechů 30:2.

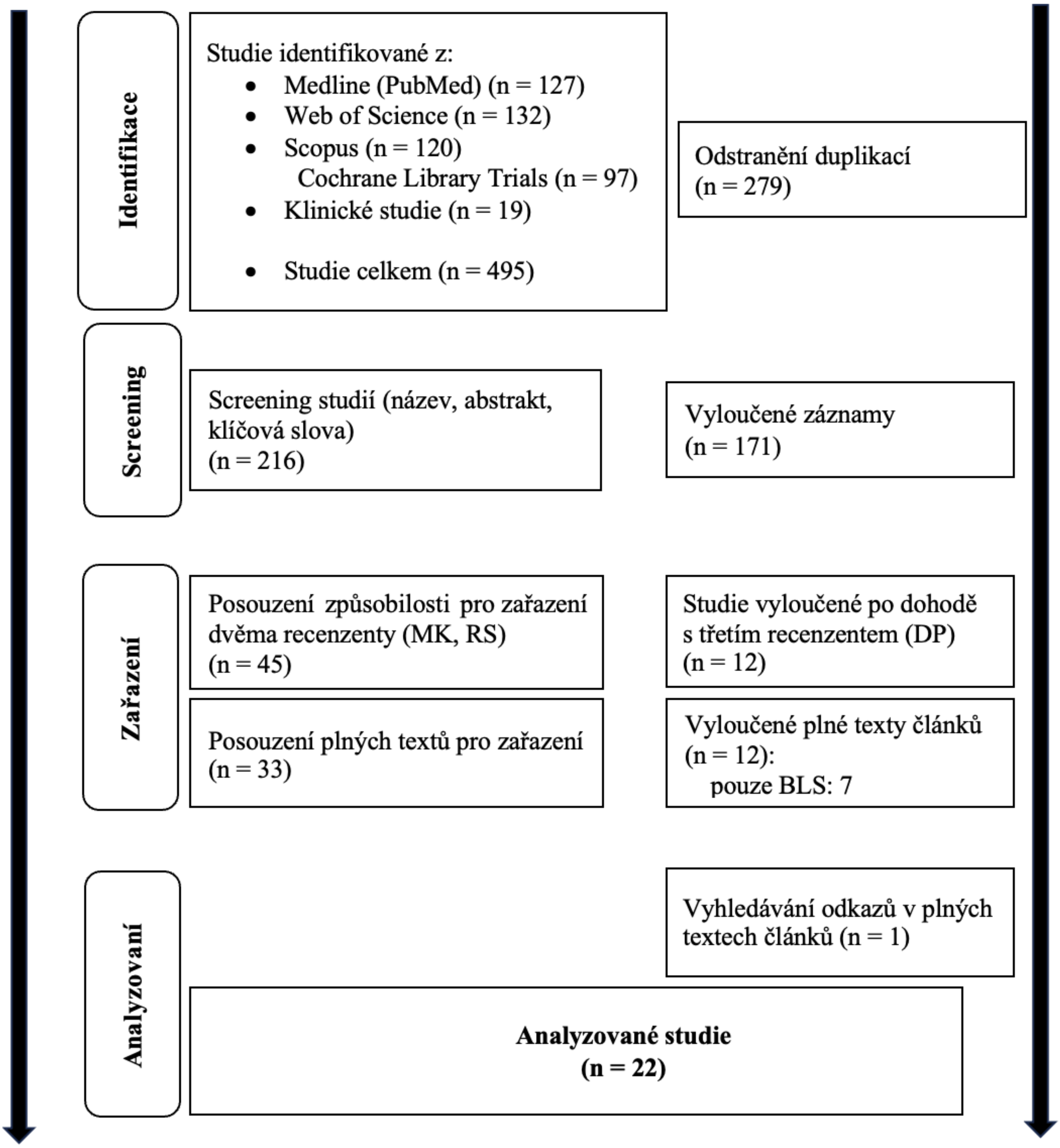
Kritéria výběru studií vycházela z rámce PICOS (Amir-Behghadami, Janati 2020):

- Populace: Dvoučlenné týmy provádějící KPR (Advanced Life Support – ALS) v mimonemocničním prostředí.
- Intervence: Sledování strategie poskytování KPR dvoučlennými týmy dospělým pacientům (starším 18 let), včetně simulací, a to jak u defibrilovatelných, tak u nedefibrilovatelných rytmů OHCA.
- Srovnání: Jakékoli srovnání, včetně žádného.
- Výsledek: Jakékoli výsledky (klinické nebo simulované).
- Design studie: Žádná omezení týkající se typu výzkumu, designu studie nebo prostředí.

Vyloučeny byly studie zaměřené na náhlou zástavu oběhu u dětí , na specifické scénáře zástavy oběhu (např. během transportu, v letectví, na moři, při sportovních událostech). Zdroje charakteru:kazuistiky, dopis, úvodník, abstrakta, systematický přehled a protokol studie, byly sledovány, ale nebyly zahrnuty do analýzy.

Počáteční vyhledávání v databázích PubMed a Web of Science stanovilo klíčová slova a vyhledávací strategie. Další vyhledávání bylo provedeno v databázích PubMed, Web of Science, Scopus, Cochrane Library Trials a ClinicalTrials.gov s cílem nalézt relevantní práce včetně protokolů studií. Rešeršní strategie a analýza titulů a abstrakt je velmi detailně popsána v příloze 4 (Supplementary material)

Na získaných publikacích byla provedena obsahová analýza, která byla rozdělena do kategorií podle témat.



Obr. 5 Rozšířené resuscitace dospělých u dvoučlenných výjezdových skupin – study-flow diagram.

8.3 Výsledky

Výsledkem počátečního vyhledávání bylo 216 článků. Po odstranění duplicit a analýze abstrakt bylo posouzeno 33 plných textů článků, z nichž 22 bylo zahrnuto do konečné analýzy. Proces výběru je podrobně popsán ve vývojovém diagramu PRISMA-ScR (viz obr. 5 výše).

Studie zahrnovaly dominantně simulační studie (n=21) a jednu přednemocniční klinickou studii. V devatenácti studiích byly použity kvantitativní metody a ve třech smíšené metody. Dvanáct studií se výslovně zaměřilo na dvoučlenné týmy, zatímco ostatní je zahrnovaly za účelem řešení různých cílů.

Studie byly roztříděny do sedmi kategorií:

- **Vliv konfigurace týmu.** Jedna studie zkoumala vliv konfigurace týmu poskytující ALS na klinické výsledky (Eschmann et al. 2010) a pět studií na kvalitu KPR (Bayley et al., 2008; Martin-Gill, Guyette and Rittenberger, 2010; Tsai et al., 2020; Krzyżanowski et al., 2021; Robakowska et al., 2022). Retrospektivní klinická studie s 10 057 pacienty s OHCA nezjistila žádný přínos pro přežití při práci více než dvou záchranářů. Simulační studie naopak ukázaly, že větší týmy zajišťují lepší kvalitu a účinnost KPR. Dvoučlenné týmy byly náchylnější k chybám a pomalejší při většině úkonů, s výjimkou tracheální intubace (Bayley et al. 2008).
- **Časné zajištění dýchacích cest.** Pět simulačních studií hodnotilo časné zajištění dýchacích cest a ventilaci dvoučlennými posádkami. V jedné cross-over studii vedla asynchronní ventilace pomocí dýchacích cest s laryngeální maskou (LMA) prováděná lékařem k vyšším dechovým objemům (Dundar et al. 2021). Studie proveditelnosti ukázaly různou úspěšnost zajištění dýchacích cest záchranáři, přičemž výsledky týkající se účinnosti a kvality byly smíšené (Guyette et al., 2006; Brucke et al., 2007; Siebers et al., 2009; Ventzke et al., 2011).
- **Využití mechanického stlačování hrudníku.** Tři simulační studie hodnotily mechanická zařízení pro stlačování hrudníku (např. LUCAS, Autopulse a další) a zjistily zlepšení kvality stlačování hrudníku a dodržování ALS protokolu (Choi et al. 2016; Kłosiewicz et al. 2021; Klosiewicz et al. 2020). Experimentální studie prokázaly hlubší stlačení hrudníku a snížení počtu neadekvátních kompresí (Klosiewicz et al. 2020; Kłosiewicz et al. 2021).

- **Využití předplněných stříkaček s život zachraňujícími léčivy dle doporučení.** Tři simulační studie se zaměřily na použití předplněných injekčních stříkaček a uváděly zkrácení doby do podání adrenalinu a rychlejší intravenózní nebo intraoseální přístup (Robak et al., 2020; Zalewski, Puslecki, et al., 2020; Zalewski R, 2020). Jedna studie také zaznamenala zlepšení frakce kompresí hrudníku a rychlejší zajištění dýchacích cest.
- **Využití dalšího vybavení.** Čtyři simulační studie zkoumaly další vybavení. Nalepovací defibrilační elektrody zlepšily kvalitu komprese hrudníku a rychlost defibrilací (Zalewski, Pu´slecki, et al. 2020). Studie proveditelnosti zjistila vysokou úspěšnost intraoseálního přístupu (Guyette et al. 2006). Použití metronomu snížilo odchylky v rychlosti komprese a ventilace (Kern et al. 2010). Prototyp resuscitačního asistenčního zařízení nezlepšil dobu „hands-off" a negativně ovlivnil kvalitu KPR (Nitzschke et al., 2017).
- **Úpravy protokolu.** Dvě simulační studie zkoumaly úpravy protokolu pro dvoučlenné posádky poskytující ALS (Choi et al. 2016; Asselin et al. 2018). Automatizovaný, na cíl zaměřený protokol OHCA zlepšil hloubku komprese, minutovou ventilaci a podávání léků a zároveň snížil fyzickou námahu a pracovní zátěž.
- **Pracovní zátěž a fyzická námaha.** Studie pracovní zátěže a fyzické námahy zjistila, že umístění batohu s vybavením kolem (obecně ergonomii) pacienta ovlivňuje kvalitu KPR, efektivitu práce, námahu a biomechanickou zátěž během simulované OHCA (Harari et al. 2020).

Jednotlivé studie jsou shrnuty detailně v tab. 6 a příloze č. 4.

Autor a rok	**Země**	**Design studie**	**Metodika**	**Typ**	**Hlavní téma**
Asselin (2018)	USA	Randomizovaná, kontrolovaná	Mixed methods	Simulační	Pracovní zátěž a fyzické úsilí
Bayley (2008)	USA	Two group design	Kvantitativní	Simulační	Složení týmu
Brucke (2007)	Německo	Studie proveditelnosti	Kvantitativní	Simulační	Adaptace doporučení
Choi (2016)	USA	Randomizovaná, kontrolovaná	Kvantitativní	Simulační	Adaptace doporučení
Dundar (2021)	Turecko	Randomizovaná, cross-over	Kvantitativní	Simulační	Management zajištění DC
Eschmann (2009)	USA	Restrospektivní, observační	Kvantitativní	Klinická	Složení týmu
Guyette (2006)	USA	Studie proveditelnosti	Kvantitativní	Simulační	Adaptace doporučení
Harari (2020)	Izrael	Experimentalní, observační	Kombinované metody	Simulační	Pracovní zátěž a fyzické úsilí
Kern (2010)	USA	Randomizovaná, kontrolovaná	Kvantitativní	Simulační	Adaptace doporučení
Klosiewicsz (2020A)	Polsko	Randomizovaná, cross-over	Kvantitativní	Simulační	Mechanické komprese hrudníku
Klosiewicsz (2020B)	Polsko	Randomizovaná, cross-over	Kvantitativní	Simulační	Mechanické komprese hrudníku
Krzyzanowski (2021)	Polsko	Randomizovaná, kontrolovaná	Kvantitativní	Simulační	Složení týmu
Martin-Gill (2010)	USA	Randomizovaná, kontrolovaná	Kvantitativní	Simulační	Složení týmu
Nitzschke (2017)	Německo	Randomizovaná, kontrolovaná	Kvantitativní	Simulační	Přídatné vybavení
Robak (2020)	Polsko	Randomizovaná, kontrolovaná	Kvantitativní	Simulační	Předplněné stříkačky

Robakowska (2022)	Polsko	Randomizovaná, kontrolovaná	Kvantitativní	Simulační	Složení týmu
Siebers (2009)	Německo	Studie proveditelnosti	Kvantitativní	Simulační	Management zajištení DC
Tsai (2020)	Taiwan	Randomizovaná, vice skupin	Kombinované metody	Simulační	Složení týmu
Ventzke (2011)	Neměcko	Studie proveditelnosti, dvě skupiny	Kvantitativní	Simulační	Management zajištení DC
Zalewski (2020A)	Polsko	Randomizovaná, cross-over	Kvantitativní	Simulační	Management zajištení DC
Zalewski (2020B)	Polsko	Randomizovaná, cross-over	Kvantitativní	Simulační	Předplněné stříkačky
Zalewski (2020C)	Polsko	Randomizovaná, cross-over	Kvantitativní	Simulační	Předplněné stříkačky

Tab. 6 Výsledky studie Rozšířená resuscitace dospělých v podání dvoučlenných výjezdových skupin záchranné služby

8.4 Diskuse

Tato přehledová studie poukazuje na nedostatek silných důkazů potřebných k vytvoření návrhu protokolu rozšířené resuscitace pro dvoučlenné výjezdové skupiny ZZS. Prezentované studie jsou velmi metodologicky heterogenní, s absencí klinických dat, popisují prakticky jen výsledky simulací. Některé intevence, jako mechanické stlačování hrudníku (Choi et al., 2016; Nitzschke et al., 2017), předplněné injekční stříkačky (Stevens et al., 2015; Zalewski, Puslecki, et al., 2020a, 2020b) a protokoly s podporou automatizace, by mohly zlepšit výkonnost dvoučlenného týmu.

Většina výzkumů byla provedena prostřednictvím simulačních studií a studií proveditelnosti s různými metodami. Větší týmy mají tendenci dělat méně chyb a dosahovat lepších výsledků v oblasti zajištění dýchacích cest a kvality KPR. Pouze jedna retrospektivní studie (Eschmann et al. 2010) hodnotila klinické výsledky pacientů s OHCA ošetřovaných dvoučlennými posádkami.

Simulační studie identifikovaly některá témata pro optimalizaci postupů rozšířené resuscitace. Včasné zajištění dýchacích cest je předmětem diskusí, ale supraglotické zajištění dýchacích cest může být stejně účinné jako endotracheální intubace (Penketh, Nolan 2023; Forestell et al. 2024; Stuby et al. 2021; 2022; Benger et al. 2022). Použití laryngeální masky může umožnit jednomu záchranáři pokračovat v kompresi v poměru 30:2, zatímco druhý se připravuje na další úkoly.

Mechanické (přístrojové) stlačování hrudníku, i když se rutinně nedoporučuje, může záchranáře uvolnit pro další úkoly. Předplněné injekční stříkačky jsou praktické, ale představují problém při skladování a organizaci léčiv. Intraoseální přístup je rychlý a může ušetřit čas. Používání jednorázových elektrod a metronomů je v současné praxi akceptováno jako doporučené.

Doporučení pro rozšířenou resuscitaci se zaměřují na výsledky u pacientů, ale méně na praktičnost jednotlivých kroků v různých podmínkách přednemocniční péče. Neexistuje žádný komplexní protokol pro dvoučlenné posádky, který by optimalizoval kroky doporučeného resuscitačního úsilí.

Přestože se jedná o běžný klinický stav, není tato problematika dostatečně prozkoumána a klinická doporučení jsou v současné době nedostatečná.

8.5 Závěr

Toto scoping review odhalilo výrazný nedostatek důkazů podporujících vysoce kvalitní provádění pokročilé resuscitace (ALS) v rámci dvoučlenných výjezdových týmů. Zároveň poukázala na zásadní význam simulačních studií, neboť realizace rigorózních klinických experimentů v přednemocničním prostředí naráží na metodologická omezení. Na základě dostupných dat proto nelze v současnosti doporučit žádnou specifickou úpravu protokolu ERC ALS pro dvoučlenné týmy zasahující u náhlé zástavy oběhu. Zjištěná mezera v evidenci podtrhuje potřebu systematického a kvalitního výzkumu, zejména formou vysoce věrné simulační medicíny, která nabízí bezpečnou a validní platformu pro ověřování nových postupů před jejich zavedením do klinické praxe.

9 Souhrnná diskuse disertační práce

Tato práce si od svého začátku klade komplexní otázku hodnocení problematiky vzdělávání, testování a ověřování klinických postupů. Dále pak na přípravu vzdělávacích programů, jejich analýzu, jak v péči o pacienta v nemocnici, tak v rámci PNP. Jak již z práce samotné vyplývá, jedná se o pole, které je velmi široké a spravedlivě nelze provést podrobnou analýzu ve všech oblastech simulační medicíny. Vybrané studie ukazují možnou šíři zapojení simulační medicíny do výuky, praxe a výzkumu.

Studie	PPE	Sufentanil NLZP	NTS v PNP	ALS dvoučlenných skupin
Ověření bezpečnosti klinických postupů	ANO	ANO	ANO	NE
Evaluace NTS v přednemocniční péči	NE	NE	ANO	ANO
Evaluace NTS v nemocniční péči	ANO	NE	NE	NE
Změny klinických postupů	ANO	ANO	NE	NE
Využití na kompetenci závislé vzdělávání	NE	ANO	NE	ANO

Tab. 7 Tab. zahrnutých studií do disertační práce a schématické znázornění tematického průniku simulační medicíny.

Studie osobních ochranných prostředků poskytuje analýzu postupů, které se v průběhu dramatické krize COVID-19 velmi měnily. Bylo nutné ověřovat řešení nejen biologické ochrany personálu a pacientů, ale také se zaměřit na netechnické dovednosti. NTS hrají zásadní roli v bezpečnosti zdravotní péče.

Dalším cílem studia bylo vytvoření vzdělávacího programu, který by obsahoval simulační výuku pro zdravotnické záchranáře. Byla vybrána oblast vzdělávání zdravotnických záchranářů, tak aby se jejich kompetence a samostatnost zvyšovala, tak jako to je častým trendem v jiných zdravotnických systémech. Samotné udělování kompetencí je poměrně více svázáno českou legislativou. Legislativně jednodušší a do praxe snadněji převeditelné se zdá být protokolární podávání léčiv. Kompetenční modely vzdělávání pro NLZP jsou účinné. Studie podávání sufentanilu ukazuje cestu, jak pomocí trojstupňového rámce (simulační trénink → teoretický test → praxe pod dohledem) lze rychle posílit kapacitu ZZS bez ztráty kvality péče.

Studie hodnocení netechnických dovedností v přednemocniční péči ukazuje poměrně vysokou míru využití efektivní komunikace, především u KPR. Tak jak je zmíněno v původním článku se nejspíš jedná o vliv dlouho zavedených kurzů, které kladou důraz na kvalitní trénink NTS. Úspěšné použití zjednodušeného TEAM skóre v reálném provozu otevírá možnost kontinuálního auditu týmové práce během PNP alespoň u vícečlenných posádek.

Ověřování klinických postupů a hodnocení v simulaci bylo poměrně extenzivně popsáno ve studii PPE. Klinická praxe však ukazuje, že i další doporučení, jako například resuscitace dospělých může být náročná k adherenci ke standartním doporučením. Provedení scoping review mapovalo oblast publikací vztažených ke dvoučlenným týmům u resuscitace dospělých. Toto review ukazuje důležitost simulačních studií. Na základě zkušeností, dostupné literatury a provedených studií se nám otevírá další pole pro zkoumání v simulačních či klinických studiích. Budoucím cílem může být vytvoření adaptivního simulačního protokolu ALS, který otestuje různé rozdělení rolí ve dvoučlenných týmech. Následně bude nutná translace studie a ověření v klinickém prostředí.

Budoucí směry, kam naše studie směřují jsou např.: navázat na PPE data dlouhodobou simulací (≥ 3 h) s měřením únavy a kognitivní zátěže pomocí objektivních škál. Takovýto protokol může přesněji odrážet klinickou praxi. Realizovat multicentrickou RCT ověřující bezpečnost protokolárního podání sufentanilu u dalších etiologií bolesti. Je však nutné vždy dodržet striktní bezpečnost protokolu. Kombinovat TEAM skóre s objektivními biometrickými indikátory (sledování rychlosti pohybu očí, měření tepové frekvence) pro komplexnější měření NTS. Vytvořit adaptivní simulační protokol ALS, který otestuje nové přerozdělení rolí a pomůcek ve dvoučlenných týmech a následně pilotovat studii v klinickém prostředí.

Soubor čtyř studií potvrzuje, že simulační medicína je efektivní nástroj pro bezpečné inovace, kompetenčně založený rozvoj a experimentální prostředí pro adaptace nových klinických postupů. Limitace jednotlivých projektů — především krátké scénáře, omezené vzorky a subjektivní metriky — vyžadují opatrnou interpretaci a navazující klinické ověření. Přesto výsledky poskytují silný argument pro systematické začlenění simulačních metod do kontinuálního vzdělávání i do procesu tvorby klinických doporučení. Při respektování identifikovaných limitů lze očekávat, že simulační medicína bude dále klíčovým rozhraním mezi pedagogikou a klinickým výzkumem a významně přispěje ke zvyšování kvality a bezpečnosti péče.

10 Limitace

Tato disertační práce syntetizuje aktuální poznatky o simulačním vzdělávání, rozvoji netechnických dovedností, kompetenčně orientované výuce a implementaci klinických změn iniciovaných simulačním tréninkem. Konkrétní limitace jednotlivých prací uvádíme v tabulce níže. Simulační medicína zůstává především pedagogickým nástrojem, avšak zároveň poskytuje experimentální platformu pro testování hypotéz a mapování komplexních klinických problémů. Novou výzvu představuje využití simulačních dat k modifikaci léčebných algoritmů; jakákoli takto navržená inovace však musí být verifikována v robustních klinických studiích, které jsou nezbytné pro translaci poznatků do rutinní praxe. Samotné simulační studie jsou přitom logisticky náročné – vyžadují rozsáhlé personální zajištění a obtížně dosahují dostatečné velikosti vzorku, což klade vysoké nároky na jejich plánování a realizaci.

11 Shrnutí

Disertační práce shrnuje možnosti vlivu simulační medicíny jako výukové metody, ale i její využití pro výzkumné účely a ovlivnění klinické praxe. Byly realizovány studie, které měnily klinický postup, jak v přednemocniční, tak nemocniční praxi. Simulace se potvrdila jako vhodná metoda pro zkoumání netechnických dovedností, které je však nutné dále analyzovat v klinické praxi, tak jak autoři provedli. Autorům se podařilo vytvořit vzdělávací program, testovat doporučení pro klinickou praxi, adaptovat a hodnotit technické i netechnické dovednosti. Dále se otevírají oblasti, kde již má a bude mít simulační medicína své místo.

12 Summary

The dissertation thesis summarizes the impact of simulation medicine and its use in clinical practice. Studies have been conducted that have altered clinical practice, both in pre-hospital and in-hospital practice. Simulation has been confirmed as a suitable method for exploring non-technical skills that need to be further analysed in clinical practice, as the authors have done. The authors were able to develop a training program, test recommendations for clinical practice, and adapt and evaluate technical and non-technical skills. Furthermore, they open other areas where simulation medicine already has and will have a place.

13 Seznam použitých obrázků a tabulek

Seznam použitých obrázků:

Seznam použitých tabulek:

14 Seznam použitých zkratek

3. LF UK	3. lékařská fakulta Univerzity Karlovy
ALS	Advanced Life Support
ANTS	Anaesthetists' Non-Technical Skills
ATLS	Advenced Trauma Life Support
CA	Cardiac arrest
CBME	Competence Based Medical Education
CDD	Centres for Disease Control and Prevention
CONSORT	Consolidated Standards of Reporting Trials
COVID	Corona Virus Disease
CPR	Cardiopulmonary Resuscitation
ČRR	Česká resuscitační rada
ERC	European Resuscitation Council
FFP	Filtering Face Pieces
ICU	Intensive Care Unit
KPR	kardiopulmonální resuscitace
NLZP	nelékařský zdravotnický personál
NOTECHS	Non-Technical Skills for Pilots adapted for Healthcare
NRS	Numeric Rating Scale
NS	Not Significant
OHCA	Out of Hospital Cardiac Arrest
PPE	Personal Protective Equipment
PTSD	Posttraumatická stresová porucha
SBAR	Situation Background Assessment Recommendation
SpO2	Saturace periferní krve kyslíkem
SSS	Super Safe Set-up

SZÚ	Státní zdravotní ústav
TEAM	Team Emergency Assessment Measure
VS	výjezdová skupina
WHO	World Health Organisation
ZZS	zdravotnická záchranná služba

15 Zdroje

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18 Přílohy

18.1 Příloha č. 1 – článek v původním znění Vliv osobních ochranných pomůcek v simulované krizi

Influence of additional personal protective equipment on team performance in simulation-based emergency scenarios: a randomised controlled trial

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Keywords: COVID-19; human factors; non-technical skills; personal protective equipment; simulation; TEAM score

Editor—Wearing personal protective equipment (PPE) not only reduces acquisition of transmittable diseases, but it can also provide a sense of comfort and safety.[1,2] Perhaps for this reason, during the recent COVID-19 pandemic, frontline hospital staff often used PPE well beyond the standard consistently recommended by public health authorities such as WHO[3] or Public Health England[4] recommendations (WHO-PPE).

Examples of additional protective measures include hooded coveralls, shoe covers, double eye protection (goggles and face shield worn at the same time), or the use of more than one pair of gloves. This practice, termed super-safe setting PPE (SSS-PPE), penetrated local policies and hospital guidelines despite evidence suggesting that it can increase physical load and impair tactile sensitivity and manual dexterity[1,5,6] and no evidence that it brings additional protection.[7] We therefore hypothesised that SSS-PPE is inferior to WHO-PPE in terms of medical personnel and team performance during emergencies and impairs patient-centred outcomes.

We designed a prospective, randomised, controlled, high-fidelity simulation-based study, using a scenario of a medical crisis resulting in the need of cardiopulmonary resuscitation (CPR). The study protocol was registered at ClinicalTrials.gov (NCT04742426) and approved by the Research Ethics Board of the Third Faculty of Medicine of Charles University in Prague. All participants gave prospective, written informed consent. We recruited 22 doctors and 44 nurses from the Department of Anaesthesia and Intensive Care Medicine for the study, all experienced in caring for ventilated patients with COVID-19. The mean age of participants was 30 (SD 6) yr, the median length of practice was 3 yr, and 79% of participants were women. Participants were divided into 22 teams of three participants, each team consisting of one doctor and two nurses. This powered the study to 80% probability of detecting a 25% difference in Team Emergency Assessment Measure (TEAM) scores[8] (the primary outcome) between groups with a significance level of $P<0.05$.

Baseline performance was assessed during the introductory 10-min simulated scenario, during which the participants wore only non-sterile gloves (Scenario 1 in the Supplementary material). After this, the teams were randomised in a 1:1 ratio, using blocks of two sealed envelopes, to determine whether they would be allocated to WHO-PPE (long-sleeved gown, protective shield, FFP2 respirator, surgical cap, and one pair of non-sterile gloves)[3,4] or SSS-PPE used routinely in COVID-19 wards at the time (hooded coverall, FFP3 respirator plus surgical mask, protective shield/goggles, three pairs of protective gloves, surgical cap, and shoe covers). They then went through the 10-min test scenario, which involved a patient with COVID-19 suffering a cardiac arrest as a result of hypoxaemia during failure of tracheal intubation (Scenario 2 in the Supplementary material), and concluded with a structured debriefing.

The primary outcome measure was team performance assessed by the TEAM score.[8] The TEAM score is a validated scoring system in which an observer awards a score between 0 (never observed) and 4 (always observed) for 11 features showing positive team attitudes and behaviours. For the first four scenarios, the scoring was performed independently by three fully trained observers familiar with TEAM score. They reached an inter-rater correlation coefficient of 0.958 (excellent reliability), and the remaining scenarios were scored by only one observer (see Supplementary material for details). In addition to the TEAM score, participants self-assessed their performance with a score ranging from 1 to 10 points, with higher scores meaning better performance.[8] Secondary outcomes were objective, patient-centred indices measuring the quality and timelines of CPR. We also recorded changes of physiological values: oxygen saturation (SpO_2), heart rate, and tympanic body temperature in the rescuers. Record-level data were collected in Excel (Microsoft, Redmond, WA, USA) and analysed using the statistical software R version 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria) with graphical user interface RStudio version 2022.07.2 (RStudio, Inc., Boston, MA, USA). We used Tidyverse data science library collection version 1.3.2 (https://www.tidyverse.org/packages/) for data wrangling and graphical displays.

We recruited and successfully conducted scenario per-protocol in all 22 teams. There were no differences in their baseline characteristics. We found a statistically significant difference in TEAM scores in the SSS-PPE group compared with the WHO-PPE group (TEAM total score 30.6 [5.6] *vs* 36.2 [5.0], $P=0.030$). Individual components of the TEAM score are shown in Fig 1. The reduction in TEAM score in the SSS-PPE group was mainly as a result of worse performance in complex tasks such as situation reassessment and anticipation of potential actions. Nonetheless, there were no differences in the overall quality of CPR (average Laerdal index 11.5 [1.4] *vs* 11.2 [4.3] points, $P=0.401$), or times to CPR milestones, such as time to start of

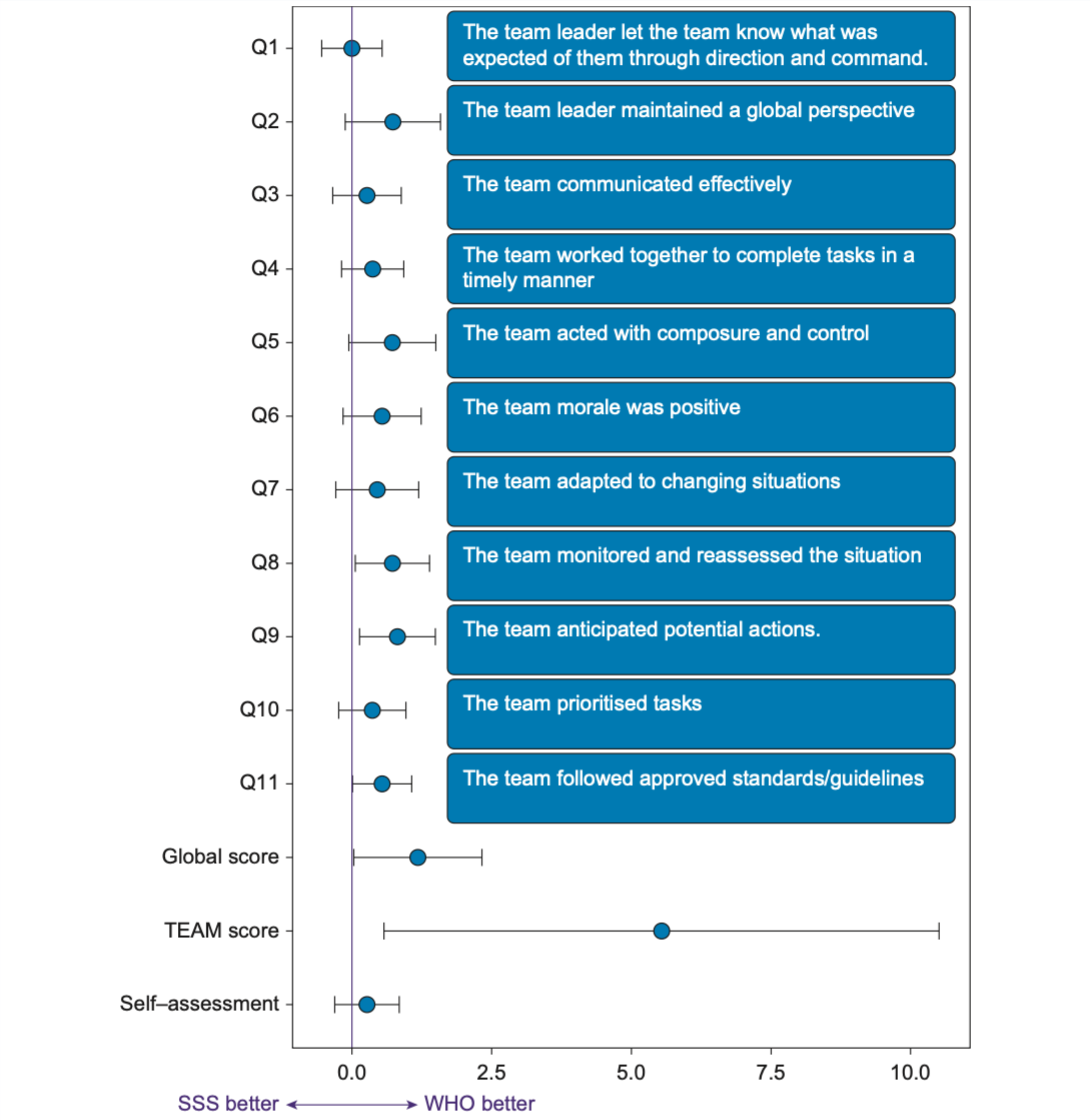

Fig 1. Differences between the WHO and SSS groups in individual components of the Team Emergency Assessment Measure (TEAM). Dots represent means and horizontal lines 95% confidence intervals. SSS, group in super-safe setup (intervention group); WHO, personal protective equipment as per World Health Organization recommendation (control group).

chest compressions, time to first effective breath or time to securing the airway, and time to epinephrine administration. Measured physiological functions of the rescuers did not differ either (see full results in the Supplementary material).

In view of the low probability that enhanced PPE increases staff safety,[7] our results in the context of other studies[9,10] bring further evidence against the common practice of deviating from the recommended standards by adding additional protective measures. That SSS-PPE is becoming seen as mandatory might still have the psychological benefit of staff feeling safer, but the impairment of soft skills remains a concern. In this small study we did not find any differences in the physiological values of the healthcare workers. However, we started with well-relaxed personnel, who wore PPE for <1 h. In real life, ICU nurses rotate in 3–6 h cycles, wearing PPE for the entirety of these shifts. It is likely that wearing additional PPE will increase fatigue and further deteriorate individual performance and soft skills. In addition, the CPR scenario, albeit time-sensitive and potentially stressful, is a situation for which teams are regularly trained and steps in the management are clear and guideline driven. There might be other situations with less clear guidelines where worse ICU team performance impacts care. This remains the major weakness of our trial, in addition to the lack of blinding of the single assessor of the primary outcome, which might induce observer bias.

In conclusion, use of SSS-PPE compared with WHO-PPE impaired non-technical skills of the team of rescuers in a simulated crisis in ICU. Physiological functions of the rescuers and quality parameters of CPR were not affected.

Acknowledgements

The authors thank Adam Whitley and Liban Jamal Mohamed for proofreading of the manuscript, the simulation centre technician Dmitriy Dinabursky for helping run the medical scenarios, and all the study participants.

Declaration of interest

The authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2023.02.028.

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doi: 10.1016/j.bja.2023.02.028
Advance Access Publication Date: 21 March 2023

Supplementary data k článku - Vliv osobních ochranných pomůcek v simulované krizi

Renza et al.: Extra Personal Protective Equipment Impairs Team Performance in Simulation-Based Randomised Controlled Trial

PPE TEAM Trial

NCT04742426 www.clinicaltrials.gov

Table of Contents

Simulation Scenarios Used in the Experiment

Scenario 1 (The Mock Scenario)

Study case 1 – WITHOUT Personal Protective Equipment (PPE)

Time allotment:

10 min

Participants:

1 physician – anaesthetist/intensivist
2 nurses – ICU

Scenario objective:
Hypoxic cardiac arrest, loss of pressure in cuff of endotracheal tube (ETT)

Expected Actions:

Resuscitation

Use ALS algorithm for non-defib rhythm (PEA)

Airway management

Clear communication in PPE

Required Equipment:

SimMan 3G
ICU room setting – ventilator, full crash cart, suction machine, defibrillator, oxygen supply, airway management equipment
PPE – surgical face mask, gloves, apron

Case story:
Time: 10 am

Location: ICU

Mr. Charles was admitted to our ICU 2 days ago. He has severe Pneumococcal pneumonia. Antibiotic therapy has been started (pneumococcus sensitive to ampicillin). There was progression to ARDS. Now he is mechanically ventilated. Nurse was doing routine hygiene. But the nurse has cut the tube from the cuff of endotracheal tube. No other physicians or nurses around.

Drugs:

Propofol 1% – 20ml/hour

Morphine 40mg/40ml saline 0,9% - 3 ml/hour

Isolyte 20ml/hour
Nadroparin – 0,6ml – 10 am (administered), 10pm
Ampicillin/sulbactam – 3g – 6am (administered), 12am, 6pm, 12pm

Lab:
5am – ASTRUP

- pH – 7,20
- Pa02 – 7,6 kPa
- PaCO2 – 5,4 kPa
- Na+ 136 mmol/l
- K+ 3,9 mmol/l
- Cl- 107 mmol/l
- Ca2+ 2,27 mmol/l
- Hgb 114g/l
- Glucose – 12 mmol/l

ALT – 0,9 µkat/l
AST – 0,81 µkat/l

BUN – 24,5 mmol/l
Creatinine – 242 mmol/l

Coagulation – in range

Beginning of simulation

Vital signs:

HR: 140/min
BP: 100/50 mmHg

Ventilation: VC-AC – PEEP 10mmHg, RR 28, Vt 400ml, FiO2 75%, loss of peep, leak!

SpO_2 85%

After 30 seconds after beginning of simulation:

SpO_2% - 85% - decrease to 30% (in 30 seconds)

HR: 140/min
BP: 100/50 mmHg

Ventilation: VC-AC – PEEP 10 mmHg, RR 28, Vt 400 ml, FiO2 75%, loss of peep, leak!

after 60 seconds after beginning of simulation:
PEA – 25 QRS actions/ min

BP: loss of pulse wave
SpO_2%: loss of pulse wave

Ventilation: VC-AC – PEEP 10 mmHg, RR 28, Vt 400 ml, FiO2 75%, loss of peep, leak!

Simulation ends after 10 minutes after beginning of simulation.

Expected management of patient:

Recognition of cardiac arrest

Start CPR
Administer epinephrine
Consider cause of cardiac arrest – recognition of hypoxemic arrest

Airway management – replacement of tracheal tube, capnography monitoring

Scenario 2 (The Test Scenario)
Study case 2 – IN Personal Protective Equipment (PPE)

Time allotment:

10 min

Participants:

1 physician – anaesthetist/intensivist
2 nurses – ICU

Scenario objective:
Hypoxic cardiac arrest, dislocation of tracheal tube

Expected Actions:

Resuscitation

Use ALS algorithm for non-defib rhythm (PEA)

Airway management

Clear communication in PPE

Required Equipment:

SimMan 3G
ICU room setting – ventilator, full crash cart, suction machine, defibrillator, oxygen supply, airway management equipment

PPE

1. Full PPE (each participant) – coverall, respirator, surgical mask, protective shield/goggles, 3 pairs of protective gloves, surgical cap, shoe cover
2. Minimal required equipment for aerosol generating procedures – gown, protective goggles, FFP2 respirator, protective gloves/shield

Case story:
Time: 10 am

Location: COVID-19 ICU

Mr. Charles was admitted to our COVID-19 ICU 4 days ago. The patient was first day at HFNO, but his $SaO_2\%$ was decreasing. On 2^{nd} day he was intubated, mechanically ventilated, prone position has been started. Now the patient was returned to supine position. No other physicians or nurses around.

Drugs:

Propofol 1% - 20 ml/ hour

Morphine 40 mg/40 ml saline 0,9% - 3 ml/ hour

Isolyte 20 ml/ hour
Supportan enteral 50 ml/ hour - STOPPED
Dexamethasone 8 mg – 6 am (administered)
Nadroparin – 0,6 ml – 10 am (administered), 10 pm
Pantoprazole 40 mg – 10 am (administered), 10 pm

Lab:
5am – ASTRUP

- pH – 7,28
- Pa02 – 8,3 kPa
- PaCO2 – 5,2 kPa
- Na+ 132 mmol/l
- K+ 4,4 mmol/l
- Cl- 104 mmol/l
- Ca2+ 2,3 mmol/l
- Hgb 121 g/l
- Glucose – 7,2 mmol/l

ALT – 1,7 µkat/l
AST – 1,3 µkat/l

BUN – 21,8 mmol/l
Creatinine – 280 mmol/l
last antiXa – 0,56 (yesterday)

Coagulation – in range
Microbiology – pending, Pneumo panel – negat. (sine antibiotics)

Beginning of simulation

Vital signs:

HR: 140/min
BP: 100/50 mmHg

Ventilation: VC-AC – PEEP 10 mmHg, RR 28, Vt 400 ml, FiO2 75%, loss of peep, leak!

SpO_2 85%

after 30 seconds *after beginning* of simulation:

SpO_2% – 85% – decrease to 30% (in 30 seconds)

HR: 140/ min
BP: 100/50 mmHg

Ventilation: VC-AC – PEEP 10 mmHg, RR 28, Vt 400 ml, FiO2 75%, loss of peep, leak!

after 60 seconds after beginning of simulation:
PEA – 25 QRS actions/ min

BP: loss of pulse wave
SpO_2%: loss of pulse wave

Ventilation: VC-AC – PEEP 10 mmHg, RR 28, Vt 400 ml, FiO2 75%, loss of peep, leak!

Simulation ends after 10 minutes after the beginning of simulation.

Expected management of patient:

Recognition of cardiac arrest

Start CPR
Administer epinephrine
Consider the cause of cardiac arrest – recognition of hypoxemic arrest

Airway management – inserting tracheal tube, correct position, capnography

Full Study Report as per CONSORT structure

Impact of Standard vs. Enhanced Personal Protective Equipment onto Team Performance During Simulated Emergency in ICU: PPE-TEAM Randomised Controlled Trial

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Abstract

Background

In the midst of the COVID-19 pandemic, healthcare professionals frequently utilized personal protective equipment (PPE) beyond guidelines established by public health agencies. The purpose of this study was to assess the impact of this additional PPE on team performance during a medical emergency.

Methods

This was a single-center, prospective, randomized, controlled, open-label study. Twenty-two teams, each consisting of a physician and two nurses, were randomized in a 1:1 ratio to either use the standard PPE recommended by the World Health Organization (WHO) or the "Super-Safe Setup" (SSE). Prior to randomization, all teams underwent a standardized mock scenario without the use of PPE to establish baseline performance. The primary outcome was team performance, which was assessed using the Team Emergency Assessment Measure (TEAM) score. Secondary outcomes included the timing and quality of cardiopulmonary resuscitation (CPR) and physiological changes of the rescuers.

Results

Compared to the standard PPE recommended by the WHO, the use of additional PPE resulted in a significant reduction in the non-technical skills of teams (TEAM score 30.6±5.7 vs. 36.2±5.0, p=0.030). This reduction was mainly due to impaired performance in complex tasks such as planning, prioritization, and following guidelines. However, there was no significant difference in the quality or timing of milestones during simulated CPR. Additionally, there were no differences in the physiological responses of the rescuers.

Conclusions

In a simulated crisis, the use of additional PPE compared to the WHO-recommended PPE resulted in a degradation of non-technical team skills. However, this did not translate into any noticeable deterioration in patient-centered outcomes, such as the quality or timing of CPR.

Key words: non-technical skills; quality of resuscitation; personal protective equipment, simulation, TEAM score

Abstract has 246 words, 5 key words.

Registration: NCT04742426 at clinicaltrials.gov

Background and objectives

Healthcare professionals rely on personal protective equipment (PPE) as a key safety measure in their daily work[1-4]. While PPE prevents the acquisition of transmittable diseases, it can also create a feeling of safety. However, wearing PPE can increase physical load and hinder interactions with patients, other healthcare workers, and the environment, which may lead to adverse events[1-4]. During the COVID-19 pandemic, ICU staff faced unprecedented challenges when working long shifts while wearing PPE in understaffed units. Studies have shown that the use of PPE in this context prolonged the time to intubation but did not affect success rates[12-14]. The effect of PPE on the quality of cardiopulmonary resuscitation (CPR) is still unclear and there is conflicting evidence[10, 15-18].

During the COVID-19 pandemic, frontline hospital staff frequently used personal protective equipment (PPE) beyond the standard recommendations of public health authorities, such as the World Health Organization (WHO)[5], the European Centre for Disease Prevention and Control (ECDC)[6], the Centers for Disease Control and Prevention (CDC)[7], and Public Health England[8-9]. The standard PPE consists of FFP2 or FFP3 respirators, goggles, gloves, and a water-resistant apron or long-sleeved gown, and is referred to in this study as WHO-PPE.

Some hospitals adopted additional measures, such as hooded coveralls (e.g., Tyvek), shoe covers, double eye protection (goggles and face shield worn simultaneously), or multiple pairs of gloves, which are collectively referred to as super-safe setting personal protective equipment (SSS-PPE). Despite the lack of evidence that SSS-PPE provides additional protection against infectious diseases[10-11], it has been incorporated into local policies and hospital guidelines. Although there is limited data on the impact of SSS-PPE on performance[17], it is reasonable to expect that the use of hooded coveralls and double eye protection may reduce the ability to hear, see, and communicate within a medical team, shoe covers may reduce gait stability, and multiple gloves may impair manual dexterity.

We hypothesized that the SSS-PPE, when compared to the standard PPE, may be associated with worse performance of individuals and the team during emergencies and, in turn, impair patient-centered outcomes. We conducted a prospective, randomized controlled study to investigate the impact of SSS-PPE, compared to standard PPE, on team performance and patient-centered outcomes in a medical crisis resulting in the need for CPR in a high-fidelity simulation setting.

Methods

Design

This study was a single-center, prospective, randomized, controlled, open-label simulation-based study that was conducted between November 2021 to April 2022. The study was a priori registered on 8th February 2021 at ClinicalTrials.gov under the number NCT04742426, and CONSORT guidelines were followed when preparing the trial protocol and the manuscript.

Setting

The study took place at the Medical Simulation Centre of the Third Faculty of Medicine, Charles University in Prague, Czech Republic, where the air-conditioned room temperature was set to 22 degrees Celsius throughout the study. The equipment of the simulation center matched the equipment used in an intensive care unit, including vital signs monitor, defibrillator, suction unit, resuscitation trolley, ventilator, oxygen supply, and airway management equipment, which was known to all study participants from routine clinical settings.

Population

Inclusion and exclusion criteria

We enrolled, by email advertisement, 22 doctors and 44 nurses on a first-come, first-served basis. Participants had to be fully registered and actively practicing in intensive care and had had exposure to looking after ventilated patients with COVID-19. There was no financial incentive, but the participation in the study was recognized as a surrogate for the yearly crisis simulation training, which is mandatory for all healthcare providers working in the intensive care unit of the University Hospital Kralovske Vinohrady. Latex allergy or other health issues incompatible with the study protocol were considered exclusion criteria.

Informed consent process

Each participant was informed about the study procedures and the broad aims of the study before signing informed consent. Details about what components of the participants performance would be measured were not disclosed before the study, but they were available to them upon request afterwards. The protocol and informed consent form were approved by the Ethical committee of the Third Faculty of Medicine of Charles University (approval number 03/2021).

Sample size

Sample size was determined based on mean TEAM performance score in a similar study[18] (3.3±0.7), therefore 22 teams (i.e., 11 teams per group) led to an 80% probability of detecting a 25% difference of TEAM scores between groups at $p<0.05$.

Study procedures in intervention and control groups

Baseline assessment

Teams were assembled randomly based on their availability at the scheduled time, with each team comprising one doctor and two nurses. All sessions began with a standardized 20-minute introduction, which aimed to familiarize the participants with the equipment and the environment. Afterward, the participants' baseline physiological values were measured, which included body temperature and oxygen saturation levels. Body temperature was measured using a non-contact thermometer on the temporal region (Geratherm Medical AG, Germany), and oxygen saturation was measured using a pulse oximeter on the right hand's index finger (Mindray PM60, United Kingdom).

Mock scenario

Next, the teams were exposed to a standardized 10-minute mock scenario (refer to Scenario 1 in the Supplementary Appendix), which involved a situation that required immediate CPR. Participants only used standard medical gloves as protective measures during this mock scenario. We recorded non-technical skills and CPR quality parameters (details below) during the mock scenario. Immediately after the mock scenario, we measured the participants' physiological values again. After this there was a 20-minute break, during which the participants were advised to rest.

Randomisation

After completing the mock scenario, the teams were randomly assigned to either the WHO PPE or SSS groups. We used blocks of two sealed envelopes to conduct randomization in a 1:1 ratio. Each participant in the SSS group wore a hooded coverall (Tyvek®, DuPont, Sandweiler-Contern, Luxembourg), FFP3 respirator (General Public s.r.o., Liberec, Czech Republic), surgical mask, protective shield/goggles, three pairs of protective gloves, a surgical cap, and shoe covers. In comparison, participants allocated to the WHO PPE used a long-sleeved, nonwoven 25g/m2 gown, protective goggles, a FFP2 respirator (General Public s.r.o., Liberec, Czech Republic), a surgical cap, and a single pair of non-sterile gloves.

Test scenario

After allocation to either the WHO PPE or SSS group the participants underwent the test scenario, which lasted for 10 minutes and involved a patient with COVID-19 who was experiencing cardiac arrest due to hypoxia caused by intubation failure (refer to Scenario 2 in the Supplementary Appendix). We recorded the same measurements as in the mock scenario before, during, and after the scenario. The session concluded with a structured debriefing.

Outcomes

Primary outcome

The study's primary outcome measure was the performance of emergency medical teams, as assessed using the validated Team Emergency Assessment Measure (TEAM).[20,21] This scoring system involves an observer rating the team's performance on eleven parameters that describe positive attitudes and behaviors, with scores ranging from 0 (never observed) to 4 (always observed) points. In addition to the individual parameter scores, there is a global score that assesses the team's overall performance on a scale of 1 to 10, with 10 being the highest possible score. The total score is the sum of the scores for each of the eleven parameters. The TEAM scoring was conducted by a trained observer (MR) who was unblinded to the team allocation. Participants also self-assessed their performance using a score ranging from 1 to 10 points, where 10 represents the highest level of performance. To ensure the reliability of the TEAM scoring tool, a second trained observer (DP, MS, VZ) performed an independent evaluation of a randomly chosen subset of four assessments to check for inter-rater variability.

Secondary outcomes

The study's secondary outcomes focused on measuring the quality and timeliness of cardiopulmonary resuscitation (CPR) using objective, patient-centered metrics. These metrics included the overall quality of resuscitation index (%), which was analyzed using Laerdal simulation software (LLEAP, version 7.3.0/winter 2021). The index takes into account the frequency and quality of chest compressions and artificial breaths, providing a comprehensive measure of resuscitation quality.

In addition, individual CPR quality indices were analyzed separately for exploratory purposes. Further details can be found in the Supplementary Appendix – Table 2.

The study also analyzed the time it took to achieve specific CPR milestones, as defined by the European Resuscitation Council Guidelines 2021.22. These milestones included the time from arrest to first chest compression (arrest recognition), time to first ventilation, time to secure airways (i.e., intubation), and the times for administering adrenaline.

Overall, the study's secondary outcomes provided a comprehensive evaluation of CPR quality and timeliness using a range of objective measures that reflect best practices in resuscitation.

Exploratory outcomes

The study's exploratory outcomes included assessing changes in physiological values among the rescuers, including oxygen saturation (SpO2), heart rate (HR), and body temperature (BT). These measures were taken before and after the resuscitation attempt to determine any changes in the rescuers' physiological status.

Statistical analysis

Statistical analysis was performed using R version 4.2.2 with graphical user interface RStudio version 2022.07.2[23,24] Data are presented as means ± standard deviations, medians (interquartile range), or percentages as appropriate. Comparisons between groups were made using the Student T-test, the Mann-Whitney U test, the Chi-Square test, or log-rank test as appropriate. Record-level data was collected in Excel and analyzed using the tidy verse data science library collection version 1.3.2 for data wrangling and graphical displays[25]. A p-value less than 0.05 was considered statistically significant for all tests.

Results

Recruitment and baseline parameters

The study recruited and successfully conducted per-protocol procedures in 22 teams (100% of target), consisting of 22 doctors and 44 nurses (Figure 1). Baseline characteristics of the participants were similar, except for a higher heart rate in the SSS-PPE group (see Table 1). Quality indices of CPR during the mock scenario were not different between the two groups (see Supplementary Appendix Table 1).

	Team members randomised to WHO (n=33)	Team members randomised to SSS (n=33)	p
Age (years; mean, SD)	30.9 (7.8)	30.0 (7.5)	0.602
Gender (%female; mean, SD)	84% (n=28)	72% (n=24)	0.228
Length of practice (months; median, IQR)	37 (8;160)	30 (8;94)	0.408
COVID-19 ward exposure (weeks; median, IQR)	12 (8;22)	10 (8;14)	0.762
Exposure to previous simulation sessions (n, self-reported; median, IQR)	4 (3;10)	5 (5;10)	0.743
TEAM Performance at baseline (mean, SD)	33.9 ± 6.7	36.5 ± 5.4	0.360
Rescuers' heart rate	100±23	114±21	**0.013**
Rescuers' SpO2	97.5±1.4	97.6±1.5	0.160
Rescuers' tympanal temperature	36.6±0.4	36.7±0.4	0.206

Table 1: Baseline study subject characteristics (differences in years/months/weeks and performance tested by Student T test, gender by Chi-Square test). Note: TEAM score measures non-technical skills of the team and ranges from 0 (worst performance) to 44 (best performance); SSS = group in super-safe setup (intervention group); WHO = personal protective equipment as per World Health Organisation recommendation (control group).

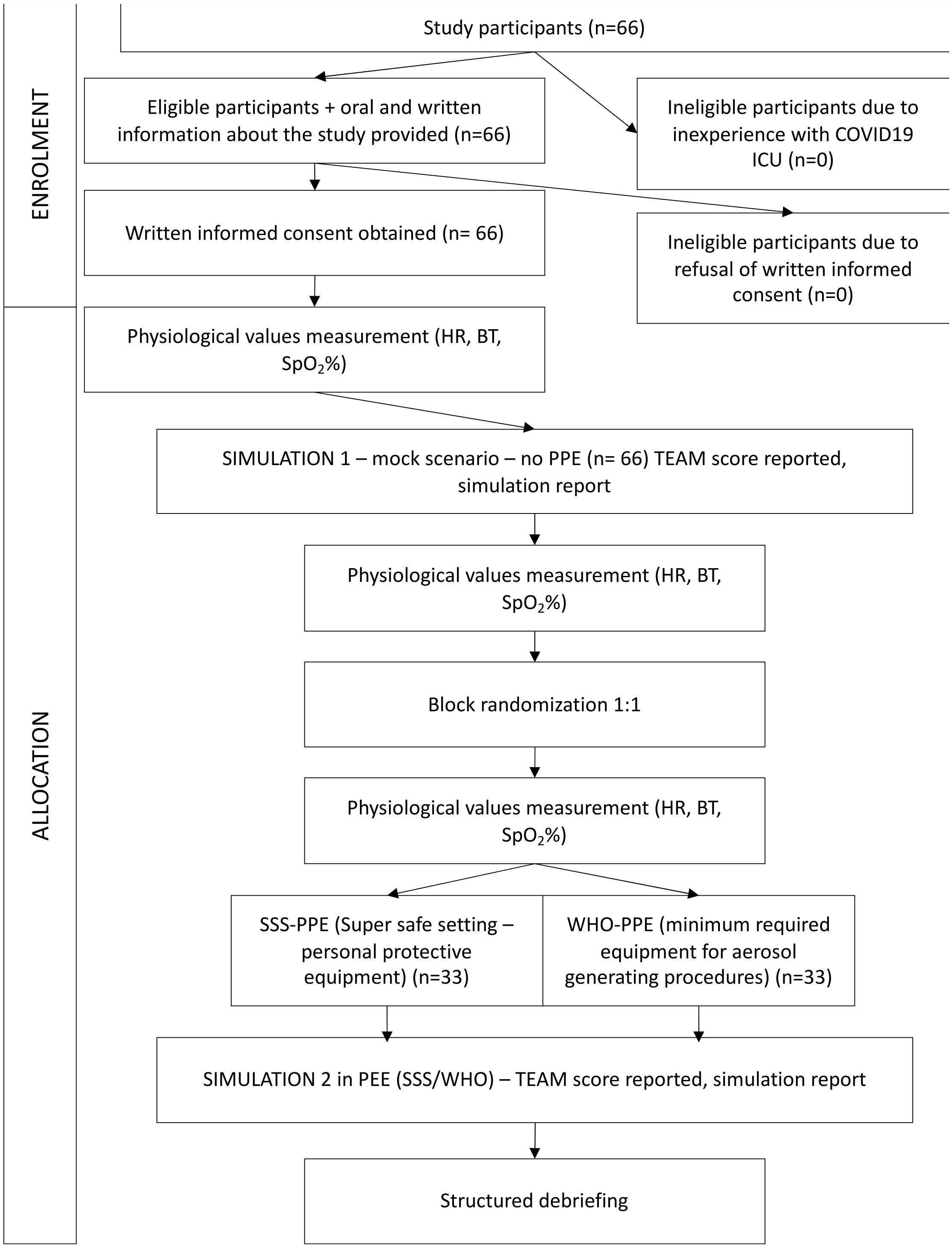


Figure 1: Study flowchart. The TEAM score is an assessment of the team's non-technical skills ranges from 0 (worst performance) to 44 (best performance). SSS = super-safe setup personal protective equipment (intervention group). WHO-PPE = personal protective equipment as per World Health Organisation recommendation (control group).

Primary outcome

The primary outcome of the study was the overall non-technical skills of the teams measured using the TEAM tool. The overall TEAM score at baseline was similar for both groups. However, the SSS group performed significantly worse compared to the WHO PPE group. The TEAM total score was 30.6±5.6 in the SSS group, compared to 36.2±5.0 in the WHO group ($p=0.030$). The TEAM global score was also significantly lower in the SSS group, with a score of 6.5 (1.4) compared to 7.7 (1.1) in the WHO group ($p=0.044$). Individual components of the TEAM score are shown in Figure 2, indicating that the reduction in TEAM score in the SSS group was mainly due to worse performance in complex tasks, such as reassessment of the situation and anticipation of potential actions.

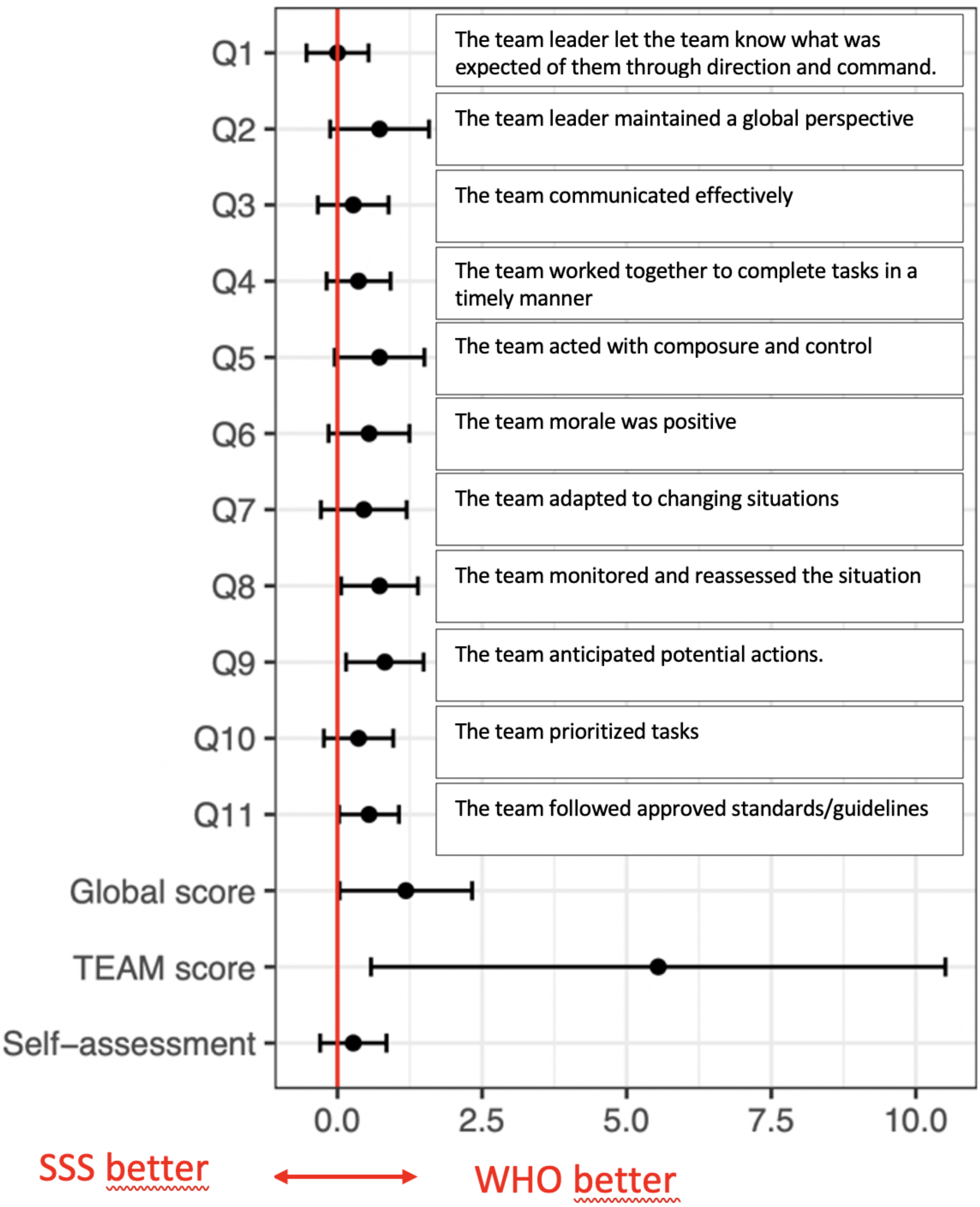


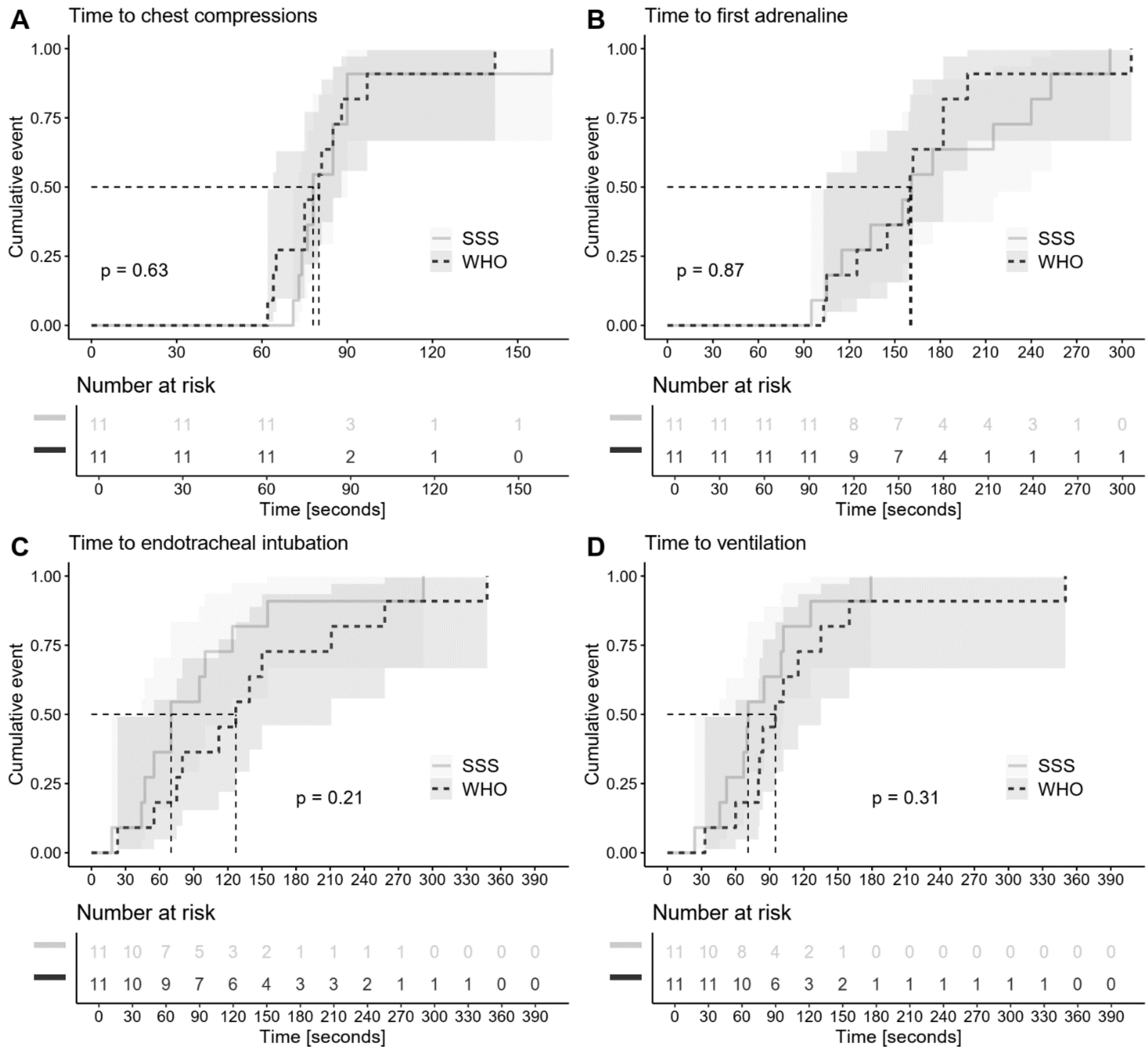
Figure 2: Differences between the WHO-PPE and SSS-PPE groups in individual components of the Team Emergency Assessment Measure (TEAM).

Dots represent means and horizontal lines 95% confidence intervals. Note: SSS = group in super-safe setup (intervention group). SSS = super-safe setup personal protective equipment (intervention group). WHO-PPE = personal protective equipment as per World Health Organisation recommendation (control group).

Secondary outcomes

There was no difference in the overall quality of CPR between the two groups, as measured by the Average Laerdal index. The SSS group scored 11.5±1.4 points, while the WHO group scored 11.2±4.3 points ($p=0.401$). Details of the components of the CPR quality indices are shown in Supplementary Appendix Figure 3. Additionally, there was no difference in the time to reach CPR milestones, such as the time to start chest compressions, time to first effective breath, or time to securing the airways and times to adrenaline administration (Figure 3).

Figure 3. Kaplan-Meier analysis of time-related secondary outcomes. SSS = super-safe setup personal protective equipment (intervention group). WHO-PPE = personal protective equipment as per World Health Organisation recommendation (control group).



Exploratory outcomes

There were no differences in measured physiological functions of the rescuers as shown in Table 2.

	Group WHO (n=33)	Group SSS (n=33)	p
End-of-session heart rate (change since baseline, bpm)	107±20 (+19±16)	118±23 (+23±16)	0.348
End-of-session SpO_2 (change since baseline, %)	97.5±1.0 (-0.3±1.8)	97.6±1.3 (-0.3±1.8)	0.945
End-of-session temperature (change since baseline, °C)	36.6±0.4 (-0.2±0.5)	36.8±0.5 (+0.13±0.5)	0.15

Table 2: Physiological changes in the participants before and after the simulated scenario.

SSS = super-safe setup personal protective equipment (intervention group). WHO-PPE = personal protective equipment as per World Health Organisation recommendation (control group).

Discussion

In our prospective, randomized controlled study, we found that adding additional PPE to the standard recommended gear decreased team performance during a simulated intensive care crisis scenario. However, we did not observe any significant differences in patient-centered objective outcomes between the two groups. Both groups achieved similar quality CPR and reached time-sensitive milestones, such as recognizing cardiac arrest, during the crisis. We also found no adverse effects on the physiological values of the rescuers. It is important to note that the management steps in CPR scenarios are clearly defined and guideline-driven, and teams receive regular training in this regard. Nonetheless, situations that lack clear guidelines could potentially result in worse ICU team performance that may negatively affect patient care.

Wearing respirators can reduce the clarity of speech, and using additional mouth coverings, such as surgical masks and face shields, can make communication more difficult or even impossible[17]. However, healthcare workers tend to compensate for these difficulties by increasing their focus and attentiveness during basic life support[26]. The impact of PPE on objective quality indices is still a matter of debate. Some studies have found that using PPE can result in a slower pace of chest compressions, less chest recoil, or incorrect compression depth, leading to worse patient outcomes[15,16,27]. However, other studies, including a meta-analysis, have shown no significant difference in the quality of CPR with the use of PPE[28,29]. Similarly, studies on the influence of PPE on manual dexterity have yielded conflicting results[17,26], but there is evidence that both intubation times[14] and the time to secure i.v. access can be prolonged[30]. Given the uncertainty surrounding the impact of PPE on CPR quality and manual dexterity, the European Resuscitation Council released modified guidelines for resuscitation in patients with confirmed or suspected COVID-19 in 2020[31].

Considering research showing that additional PPE is unlikely to increase staff safety[32-36], our study adds to the growing evidence against the common practice of deviating from recommended PPE standards by adding extra protective measures. This practice can lead to the normalization of deviation, where the additional measures become perceived as mandatory, reducing the psychological benefit of feeling safer, while impairing soft skills. Although we did not find any significant differences in the physiological values of healthcare workers in this short study, it should be noted that our personnel wore PPE for less than one hour, and in real-life situations, ICU nurses rotate in 3–6-hour cycles wearing PPE. The use of additional PPE may increase physical burden, cause fatigue, and likely deteriorate individual performance and soft skills further[17].

While our study is a prospective, randomized controlled trial with a priori registered protocol and a relatively large sample size, it does have some limitations. The primary outcome measure was based on a subjective evaluation by an evaluator who could not be blinded to arm allocation, which could introduce bias. In addition, the voluntary recruitment of participants may have led to selection bias. Moreover, the use of a simulated environment with manikins may not fully reflect real-life crisis situations. It is important to keep these limitations in mind when interpreting the results of this study and further research is needed to confirm our findings in a more representative setting.

Conclusions

Our study demonstrates that using additional PPE beyond the WHO-recommended standards can negatively impact the non-technical skills of ICU rescuer teams during a simulated crisis. However, we found no adverse effects on the physiological functions of the rescuers or on the quality parameters of CPR.

Acknowledgements

The authors thank Adam Whitley and Liban Jamal Mohamed for proofreading of the manuscript, the simulation centre technician Dmitriy Dinabursky for helping running the medical scenarios, and all the study participants.

Declaration of interests

The authors declare that they have no conflict of interest.

Funding

This research was supported from *Cooperatio* Intensive Care Medicine, P33, by Charles University in Prague, Czech Republic.

Authors' contributions

MR: Conceptualization, Methodology, Formal analysis, Resources, Writing – original draft; **DP:** Methodology, Formal analysis, Research, Writing – original draft; **RS:** Conceptualization, Research, Writing – Reviewing and Editing; **MS:** Investigation, Organisation, Writing – Reviewing and Editing; **VZ:** Conceptualization, Methodology, Organisation, Writing – Reviewing and Editing; **PW:** Formal analysis, Methodology **FD:** Conceptualization, Methodology, Supervision, Writing – Reviewing and Editing.

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Supplementary Data Visualisation

Components of TEAMS Score in Mock and Test Scenarios

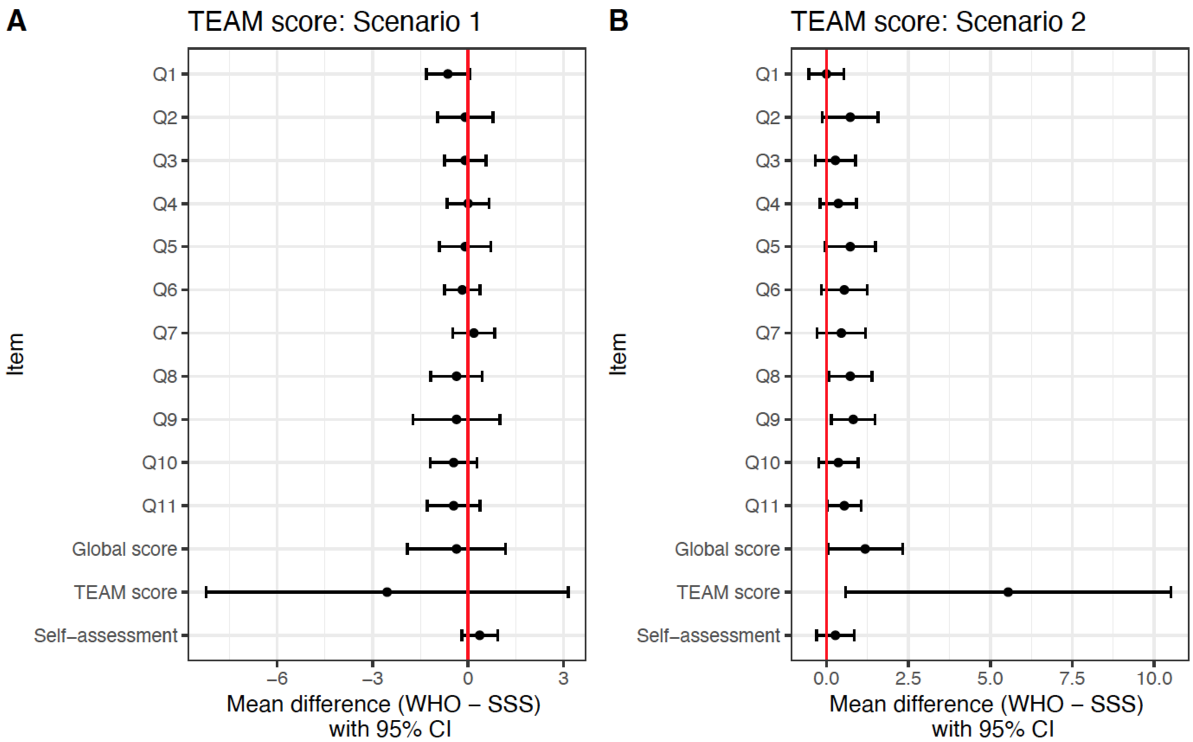

Figure S1: Differences between the WHO and SSS groups in individual components of the Team Emergency Assessment Measure (TEAM) in Scenario 1, performed at baseline with test subjects wearing no PPE but gloves. Scenario 2 is after randomisation to either wear WHO recommended PPE or super-safe setup (SSS). Dots represent means and horizontal lines 95% confidence intervals.

Detailed Data on Quality of resuscitation during MOCK scenarios

	Indices	Group 1	Group 2	p
Secondary outcomes – Quality of resuscitation	Quality overall (%)	11(10;12)	12 (11;12)	NS
	Compressions count (n)	923.81 (53.55)	879.10 (94.38)	NS
	Mean compression depth (mm)	41.55 (5.15)	42.36 (4.46)	NS
	Correct position of hands (%)	11 (3;24)	28 (17;38)	NS
	Sufficient release of chest (%)	95 (77;98)	94 (84;97)	NS
	Sufficient depth of compressions (%)	12 (1;34)	20(10;34)	NS
	Frequency of compressions average (x/min)	119.73 (8.82)	116.55 (10.95)	NS
	Correct frequency of compressions (%)	52 (33,73)	69 (51;79)	NS
	Total ventilations (n)	158.18 (71.86)	181.27 (50.96)	NS
	Mean volume (ml)	545.81 (196.30)	633.55 (116.60)	NS
	Average frequency of ventilations (x/min)	15.72 (7.20)	16.55 (5.28)	NS

	Too big ventilation volume (%)	52 (0;63)	37 (6;58)	NS
	Correct ventilation volume (%)	36 (19;45)	62 (35;73)	NS
	Too small volume of ventilation (%)	3(1;22)	4 (2,9)	NS

Detailed Quality of Resuscitation Indices During Test Scenario

	Indices	WHO	SSS	p
Secondary outcomes – Quality of resuscitation	Quality overall (%)	12 (11;12)	12 (11;13)	NS
	Compressions count (n)	955.45 (51.70)	967.63 (88.94)	NS
	Mean compression depth (mm)	40.64 (4.59)	41.72 (2.38)	NS
	Correct position of hands (%)	7 (1;9)	1 (0;6)	NS
	Sufficient release of chest (%)	82(81;98)	97 (84;99)	NS
	Sufficient depth of compressions (%)	4 (2;25)	9 (6;14)	NS
	Frequency of compressions average (x/min)	120.91 (7.52)	119.00 (9.95)	NS
	Correct frequency of compressions (%)	66 (32;74)	67 (34;88)	NS
	Total ventilations (n)	171.18 (122.10)	194.18 (50.10)	NS
	Mean volume (ml)	600.72 (141.66)	647.18 (163.73)	NS
	Average frequency of ventilations (x/min)	18.45 (11.07)	19.36 (4.57)	NS
	Too big ventilation volume (%)	21 (5;40)	54 (2;80)	NS
	Correct ventilation volume (%)	71 (31;83)	46 (21;81)	NS
	Too small volume of ventilation (%)	6 (2;8)	5 (0;7)	NS
Se	Time to first compression (sec)	83.09 (22.30)	87.45 (25.60)	NS

	Time to first ventilation (sec)	117.73 (84.40)	83.82 (42.53)	NS
	Start with bag mask ventilation first (%)	36% (n=4) Intubation first (n=7)	9% (n=1) Intubation first (n=10)	NS
	Time to intubation (sec)	143.45 (95.86)	97.27 (75.43)	NS
	Time to 1st epinephrine (sec)	166.09 (55.72)	175.36 (65.39)	0.347
	Time to 2nd epinephrine (sec)	316.09 (75.53)	347.81 (86.02)	NS
	Time to 3rd epinephrine (sec)	470.78 (52.47)	500.29 (60.47)	NS
	Administration of 3rd epinephrine (%)	82% (n=9)	64% (n=7)	NS
	Δ SpO2	-0.27 (1.80)	-0.30 (1.76)	NS
	Temperature before (°C)	36.78 (0.31)	36.71 (0.35)	NS
	Temperature after (°C)	36.60 (0.37)	36.83 (0.53)	<0.05
	Δ T	-0.18 (0.47)	+0.13 (0.54)	<0.05

Abbreviation list

ALS – Advanced Life Support
ALT – Alanine Transaminase
ARDS – Acute Respiratory Distress Syndrome
AST – Aspartate Aminotransferase
BUN – Blood Urea Nitrogen
C - Celsius
CDC- Centres for Disease Control and Prevention
CONSORT - Consolidated Standards of Reporting Trials
COVID – Corona Virus Disease
CPR – Cardiopulmonary Resuscitation
ECDC - European Centre for Disease Prevention and Control
ETT – Endotracheal Tube
FFP – Filtering Face Pieces
FiO2 - fraction of inspired oxygen
ICU – Intensive Care Unit
Lab - Laboratory
mm - millimetre
NS – Not Significant
PEA – Pulseless Electric Activity
PEEP – Positive End-Expiratory Pressure
PPE – Personal Protective Equipment
sec - second
SpO2 - Oxygen saturation
SSS – Super Safe Set-up
TEAM - Team Emergency Assessment Measure
VA-AC – Volume Control - Assist Control
Vt – Tidal volume
WHO – World Health Organisation

18.2 Příloha č. 2 – článek v původním znění Podávání sufentanilu nelékařskými zdravotnickými pracovníky bez konzultace lékaře

Renza *et al. BMC Emergency Medicine* (2022) 22:63
https://doi.org/10.1186/s12873-022-00622-8

BMC Emergency Medicine

RESEARCH **Open Access**

Pilot implementation of the competence of Czech paramedics to administer sufentanil for the treatment of pain in acute trauma without consulting a physician: observational study

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Abstract

Background: The use of intravenous opioids in the traumatic pain in pre-hospital care in the Czech Republic is based primarily on the indication of a physician. If the paramedic crew arrives at the site earlier or only on their own, analgesia is given after phone-call consultation with the physician or after his arrival at the site. The objective of this study was to evaluate the safety and efficacy of the indication and administration of sufentanil by paramedics in the treatment of pain in acute trauma adult patients without the physician's control.

Methods: Paramedics underwent voluntarily the simulation training aimed at administering intravenously sufentanil to treat pain in acute trauma in adults without physician's indication. Subsequently, the adverse events and efficacy were monitored for a six-month period and compared in two groups: administration of sufentanil by paramedics without this competence, who further consulted the administration by telephone with physicians (group Consultation) and those with this competence (group Competence).

Results: A total number of sufentanil administration in group Consultation was 88 and in group Competence 70. There was no respiratory arrest, bradypnea, or need for oxygen therapy reported in any of the study groups. The incidence of nausea was 3% in both groups – Consultation ($n = 3$) and in Competence ($n = 2$). Vomiting was not reported in the Consultation group and in 6% in the Competence group ($n = 4$). Intravenous antiemetic drugs were used in the Consultation group only in 1% ($n = 1$) and in the Competence group in 7% of patients ($n = 5$) ($p < 0{,}05$). In both groups there was observed a decrease in the pain numeric rating scale (Consultation: M = —3,2; SD = 1,2 points vs. Competence: M = —3,9; SD = 1,8 points).

Conclusion: Intravenous administration of sufentanil by properly trained paramedics without consultation with a physician in acute trauma can be considered safe.

Keywords: Prehospital care, Analgesia, Sufentanil, Paramedic, Simulation, Trauma

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Background

High quality and safe pain management is the goal of not only prehospital emergency care [1] provided by emergency medical services' (EMS) crews. In terms of competencies, systems of providing pre-hospital emergency care differ. In many European countries, also in the Czech pre-hospital emergency care, the system is historically dependent on physicians [2, 3]. Competencies of paramedics are based on specific legal norms and education of healthcare professionals and differs all around the world [4, 5]. Paramedic's crews in the Czech Republic do not have the competency to administer analgesic medication without direct supervision of or without phone-call consultation with an EMS physician [6]. It must be stated that shortage of physicians in the Czech EMS system due to personnel and economic reasons leads to an increasing emphasis on the competencies of paramedics. However, the Czech system of healthcare legislation allows the employer or organization to delegate certain competencies to paramedics within completely standard procedure in a defined situation (also known as Standard Operating Protocol). Among the growing number of competencies of Czech paramedics there is still a need to treat acute pain in acute traumatic injuries with opioids in the case of less serious cases where no ambulance crew with physician is dispatched to the scene [7]. At present, the absence of a physician in the ambulance crew on site leads to the need for a telephone consultation or a request for the arrival of a physician, which prolongs the time until effective analgesia and prolongs the patient's suffering. In addition, during and after the telephone consultation, the EMS physician is not present on the scene to address any complications.

Objectives

Primary objective of this study was to evaluate the safety and efficacy of indication and administration of the sufentanil in treatment of pain in acute trauma patients by paramedics without the physician's control.

Methods

Prior to the study a questionnaire survey focused on pain management in acute trauma among all paramedics of the EMS of Karlovy Vary Region was conducted ($n = 115$, return rate 81% ($n = 95$)). Based on main results of this survey the proposed competency to administer sufentanil by trained paramedics in acute trauma was identified as necessary for 80% ($n = 76$) of paramedics. Subsequently, this competence was determined as voluntary. A total of 39 paramedics signed up and completed training program to administer sufentanil in acute trauma. Age, gender, length of practice and level of medical education (whether university or higher professional school) were monitored in the group of paramedics who volunteered to acquire the competence. The training consisted of theoretical e-learning part (14 days prior the training) and one training session (4 h) based on medical simulations during August 2020. The training covered pharmacological and clinical information and specific indication criteria (case of acute traumatic pain without the presence of physician on site, adult patient without impaired consciousness, hemodynamic stability) and also the training of detection and management of complications, with special emphasis on respiratory depression and bag mask ventilation was trained. Sufentanil was titrated, based on clinical effect, by 5 µg up to 20 µg of maximal possible dose within this competence. The final verification of the competence of paramedics was evaluated by 3 instructors (anaesthesiologists working in EMS) during six simulation scenarios, hands-on station with bag mask ventilation and by final written exam focused on side effects, indication criteria and dose of sufentanil.

Study design

This was a single centre, prospective, observational study with two monitored groups. The educational program, definition of competence and its implementation to internal standard of care was approved by the Medical Board of Emergency Medical Services of Karlovy Vary region on 22nd of May 2020. The study protocol and conduction of the study was approved by Ethical Committee of Emergency Medical Services of Karlovy Vary Region registered with State Institute for Drug Control of the Czech Republic on 11thof September 2020 under ref. no. ZN/78/ZZSKVK/20. Informed consent was not required from patients with acute trauma pain. It was carried out within the framework of tacit consent after standard information about the planned procedure within the provision of pre-hospital emergency care according to the Czech legislation ((Health Services Act No. 2011, 372 (CZ)) [6]. The protocol of the trial was retrospectively registered at clinicaltrials.com (NCT04913402).

Study location

The study was conducted at EMS of Karlovy Vary Region, Karlovy Vary, the Czech Republic during 6-month period from 11th of September 2020 to 22nd of March 2021. A total number of 20.406 patients were treated during the study period by crews of EMS of Karlovy Vary Region.

Participants and interventions

All cases of administered sufentanil were checked from electronical patient documentation („ePaRe " – part MZD, European Medical Distribution Ltd., Bratislava, Slovak Republic). Subsequently, only events which met eligibility criteria were included in analysis. Eligibility criteria consist of a) administration of sufentanil by paramedics on site without physical presence of physician in acute traumatic pain, b) adult patients (at least 18 years old), c) no impairment of consciousness (defined as Alert and Glasgow Coma Scale = 15), d) who is hemodynamically stable (defined by systolic blood pressure > 100 mmHg and without presence of bradycardia bellow 60 beats per minute). The two study groups were identified from eligible cases of patients with pain in acute trauma, who were given sufentanil 1) by paramedics in a routine way, after telephone consultation with an EMS physician (Consultation) and 2) who were given sufentanil by competent paramedics themselves (Competency). In the Competency group, the paramedics were allowed to administer sufentanil intravenously up to 20 µg. The recommended pain Numeric Rating Scale (NRS) score for consideration of sufentanil administration was above 4 points.

Baseline characteristics of both groups were obtained from electronical patient documentation: age, gender, NACA score (National Advisory Committee for Aeronautics), type of trauma (lower or upper limb, trauma of torso, head injury), dose of sufentanil and if there was fractional dose administration, and proportion of cases where additional non-opioid analgesia (paracetamol) was used.

Outcome measures

To measure the safety and efficacy of sufentanil administration information were extracted from electronical patient documentation. Incidence of respiratory arrest (the need for bag mask ventilation); bradypnea (less than 10 breaths per minute); or need for oxygen therapy (defined as decrease of SpO_2 under 92 percent). Then the frequency of complete NRS reporting (before sufentanil administration and at the handover) were determined. Other adverse effect of sufentanil administration (incidence of nausea and vomiting and need for intravenous antiemetic drug – thiethylperazin) was evaluated. Moreover, the heart rate, blood pressure, SpO_2 and respiratory rate before sufentanil administration and at the handover were noted.

Statistical methods

No sample size was calculated prior to the study but the period of half a year was set for evaluation. Due to the character of observations and predefined groups of paramedics with and without competency no randomization or blinding was used. Baseline characteristics and outcomes among study groups were tested by t-test for ordinal and Chi-square test for nominal variables. Statistical software STATISTICA 7.0 (StatSoft, Inc., Tulsa, Oklahoma, USA) was used for statistical analysis and calculations.

Results

The selection of eligible and description of excluded cases is presented in the flow diagram (Fig. 1). Baseline characteristics of the paramedics with competency are compared with those who did not volunteer in Table 1. A total number of sufentanil administered intravenously to patients with acute trauma by paramedics after phone call consultation with EMS physician (group Consultation) was 88 and by paramedics with competency without any consultation (group Competence) was 70.

The baseline characteristics of both groups including the spectrum of injuries and pharmacotherapy is in detail described in Table 2. The dose of intravenously administered sufentanil was almost identical in both groups (Consultation: M = 9.1; SD = 2.0 micrograms vs. Competence: M = 9.4; SD = 2.4 micrograms).

In terms of reporting the occurrence of adverse events (Table 3) there was no respiratory arrest or bradypnea reported in any of the study group as well as the need for oxygen therapy after sufentanil administration. The incidence of nausea was the same in both groups: Consultation; $n = 3$ (3%) vs Competence; $n = 2$ (3%). Vomiting after sufentanil administration was not reported in the Consultation group and despite the incidence of vomiting (6%) in the Competence group ($n = 4$) this result did not reach statistical significance. Similarly, intravenous antiemetic drugs were used less frequently in the consultation group only in 1% ($n = 1$) than in the Competence group in 7% of patients ($n = 5$) (($\chi^2(1, N = 158) = 3{,}85$, $p < 0{,}05$).

In both groups there was a decrease of pain in the NRS (Consultation: M = —3,2; SD = 1,2 points vs. Competence: M = —3,9; SD = 1,8 points) without a statistically significant difference between the groups: $t(81) = -1{,}58$. $p = 0{,}059$. Complete NRS reporting was significantly more frequently reported in the Competency group in 86% ($n = 60$) compared to 26% ($n = 23$) in the Consultation group ($\chi^2(1, N = 158) = 47{,}35$, $p < 0{,}0001$). From such disproportionately reported data, a significant difference in the NRS was evident between Consultation (M = —6,4; SD = 1,5) and Competency group (M = —7,9; SD = 1,4): $t(81) = -4{,}05$, $p < 0{,}05$ as presented in Table 4.

Any significant effect of sufentanil administration on systolic and diastolic blood pressure, heart rate, peripheral oxygen saturation and respiratory rate was not observed and its differences in patients of both groups before administration of sufentanil and on handover

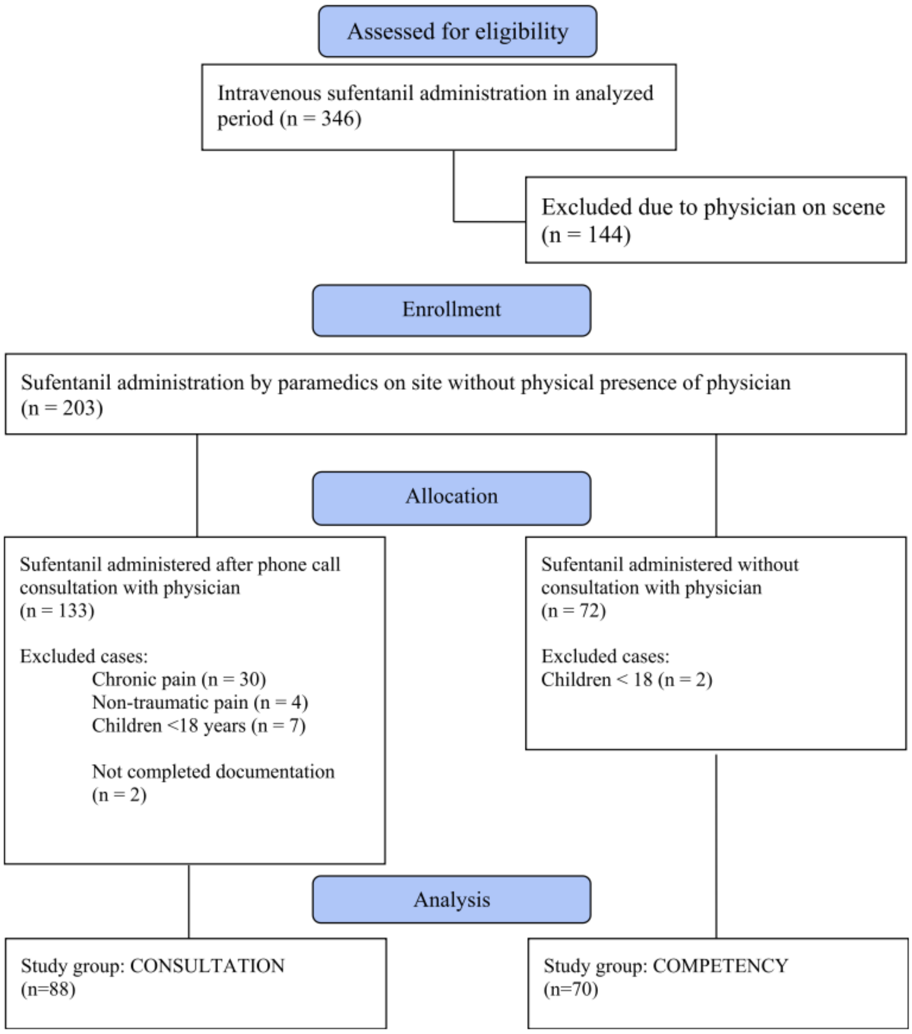

Fig. 1 Flow diagram

Table 1 Baseline statistics of group of paramedics without and with competence

	CONSULTATION ($n=76$)	COMPETENCE ($n=39$)	
Age (years)	44.7 (9.6)	44.1 (8.5)	NS
Gender (women)	63%	59%	NS
University education	28%	44%	NS*
Length of praxis (years)	21.5 (10.0)	20.4 (8.9)	NS

Data are presented as mean and standard deviation or as number and percentage

NS Not Significant

* $p=0.085$

(Table 5) and the values between both study groups did not differ significantly as well.

Discussion

This study focused on the creation of a new competence for paramedics in a physician-based system of prehospital emergency care [2], when paramedics usually do not have the competence to administer opioid analgesics. On the other hand, due to the urgency of emergency calls, paramedic's crews are often sent to cases of less serious trauma on their own without a doctor crew [7]. These trauma patients are obviously in pain and paramedics should either call a doctor on the scene or consult him for analgesia administration. From the available opioids provided in pre-hospital care in the Karlovy Vary region of the Czech Republic, the most frequently used opioid

Table 2 Sufentanil administration baseline statistics

	CONSULTATION (*n* = 88)	COMPETENCE (*n* = 70)	
Age (years)	64,6 (19,7)	65,7 (20,0)	NS
Sex (women)	61 (69%)	39 (56%)	NS
NACA score	2,5 (0,5)	2,4 (0,5)	NS
Trauma of lower limb	57 (65%)	35 (50%)	NS[a]
Trauma of upper limb	23 (26%)	22 (31%)	
Trauma of torso	8 (9%)	13 (19%)	
Trauma of head	0	0	NS
Dose of sufentanil (μg)	9,1 (2,0)	9,4 (2,4)	NS
Fractional administration	24 (27%)	20 (29%)	NS
Additional non-opioid analgesia	12 (14%)	10 (13%)	NS

Data are presented as mean and standard deviation or as number and percentage

NS Not Significant, *NACA* National Advisory Committee for Aeronautics

[a] The 3 × 2 contingency table to calculate Chi square statistics was used

Table 3 Adverse events and its treatment after intravenous sufentanil administration in trauma

	CONSULTATION (*n* = 88)	COMPETENCE (*n* = 70)	
Respiratory arrest	0	0	NS
Bradypnea	0	0	NS
Oxygen therapy after sufentanil administration	0	0	
Nausea	3 (3%)	2 (3%)	NS
Vomiting	0	4 (6%)	NS
Antiemetics administration	1 (1%)	5 (7%)	$P < 0,05$

Data are presented as number and percentage. *NS* Not Significant

Table 4 Numeric rating scale (NRS) details

	CONSULTATION (*n* = 88)	COMPETENCE (*n* = 70)	
Complete report of NRS	23 (26%)	60 (86%)	$P < 0.05$
NRS reduction (points)	-3.2 (1.2)	-3.9 (1.8)	NS
Initial NRS (points)	6.4 (1.5)	7.9 (1.4)	$P < 0.05$

Data are presented as mean and standard deviation or as number and percentage

NS Not Significant, *NRS* pain Numeric Rating Scale

sufentanil was selected. Although sufentanil is a very potent opioid [8] it has been confirmed by this study that when administered within a clearly defined indication and by well-trained paramedics, it is an effective and safe alternative to administration by telephone consultation with EMS physician. In addition, the authors believe that the paramedics training to solve complications after administration of sufentanil is beneficial not only for this particular competence, but it can also be used in other situations where the doctor prescribes by phone and is not present on the scene to solve possible complications.

In the results, there was recorded relatively few side effects, which is probably the result of strict indication criteria. Such a criteria were deliberately set very harshly to ensure that sufentanil was safe and that training was adequate. Reducing the number of phone-call consultations with an EMS physician leads to a lower burden on paramedics and physicians. This study verified that it is possible to assign other competencies based on simulation training with verification of knowledge and skills. In this study, the clinical benefit in reducing the time of patient's suffering and pain can be expected. Unfortunately, the exact time of administration of sufentanil and the possible reduction in time to its administration without consulting a physician were not monitored in this study due to operative and ethical reasons.

This single centre observational study has several limitations. One of them is that new competence was given to paramedics who voluntarily underwent training. This voluntariness could cause the bias of this study. Motivated paramedics have usually better performance than unmotivated. A very interesting finding was that among the paramedics who acquired the competence to administer sufentanil voluntarily, no difference was observed in any of the following parameters (age, gender, length of practice) compared to those paramedics who did not want the competence. However, the higher percentage of university education among paramedics who acquired competence did not gain statistical significance, probably due to the size of the sample and its disproportion.

In addition, the analysis of the results was from a relatively short period of time when it was burdened with other special conditions, especially COVID-19 patients. Due to waves of COVID-19, quarantine measures and reduced population movements, trauma in pre-hospital care has decreased.

It is certainly worth mentioning the difference in NRS reporting between groups. The study was conducted as a prospective observational study. The control group performed routine work (blinded) and only trained rescuers had to respect the new standard of care, which includes the obligation to report to the NRS when considering opioid administration [9] based on new competence. This may partly explain the difference in complete NRS reporting before and after administration of sufentanil. Likewise, paramedics who should have consulted physicians may tend to underestimate NRS and even monitor for side effects. This statement can be based on the lower need for

Table 5 Effect of intravenous sufentanil administration in trauma on physiological parameters

	CONSULTATION ($n=88$)		COMPETENCE ($n=70$)		
	On scene	Handover	On scene	Handover	
Systolic blood pressure (mmHg)	145.5 (24.1)	142.9 (20.7)	142.2 (20.8)	138.9 (16.5)	NS
Systolic blood pressure difference (mmHg)		-2.7 (13.2)		-3.3 (11.2)	NS
Diastolic blood pressure (mmHg)	78.3 (15.2)	78.1 (10.9)	79.8 (11.6)	77.5 (10.3)	NS
Diastolic blood pressure difference (mmHg)		-0.2 (11.2)		-2.2 (7.6)	NS
Heart rate (bpm)	85.9 (13.2)	84.5 (13.4)	86.0 (15.9)	83.2 (14.0)	NS
Heart rate difference (bpm)		-1.4 (8.0)		-2.9 (7.8)	NS
SpO_2 (%)	96.9 (9.8)	96.7 (2.3)	97.1 (1.7)	96.8 (1.4)	NS
SpO_2 difference (%)		-0.2 (1.8)		-0.3 (1.7)	NS
Respiratory rate (breaths per minute)	14.4 (1.5)	14.1 (1.5)	15.6 (2.6)	14.6 (1.6)	NS
Respiratory rate difference (breaths per minute)		-0.3 (1.1)		-1.1 (2.0)	NS

Data are presented as mean and standard deviation

NS Not Significant, *bpm* beats per minute, SpO_2 Oxygen Saturation

therapeutic administration of antiemetics in the control group. From these data it is possible to conclude that increasing the level of competencies of paramedics or education [10] can lead to an increase in the quality and safety of care provided thanks to a higher level of responsibility and motivation, which leads to more careful examination of patients, better focus on their needs and in the end also better medical documentation. At the same time, a group with competencies can be perceived as more proactive, as well as with a tendency towards better reporting and earlier treatment using their other competencies.

In general, the treatment of pain by opioids is still open area in emergency medicine and especially in the pre-hospital setting [11, 12]. This study focused on the administration of intravenous sufentanil in less severe traumatic injuries. So far it seems to be the first study addresses the use of intravenous sufentanil in acute trauma by paramedics without EMS physician consultation. Most studies focus on the administration of fentanyl or morphine [13], ketamine [14, 15], combination of fentanyl and ketamine [16] or on another route of administration (e.g. intranasal or transmucosal) [17–19]. Our study does not address the use of opiates in children or other medical conditions (e.g. myocardial infarction) as it was presented in other studies [13, 20].

And at the same time, this study is in agreement with other studies from similar health care systems and confirms that it is possible to entrust prehospital analgesia to trained paramedics [14]. In the end we must mention that further validation by randomized controlled trial would be beneficial.

Conclusion

Intravenous administration of sufentanil by paramedics alone without consultation with a physician (in physician-based healthcare systems) in acute adult trauma can be considered safe within the scope of trained and established competence and in compliance with the indication criteria.

Abbreviations

EMS: Emergency Medical Service; NACA: National Advisory Committee for Aeronautics; NRS: Numeric Rating Scale; NS: Not Significant; mmHg: Millimeters of Mercury; bpm: Beats Per Minute; µg: Micrograms.

Acknowledgements

Acknowledgement is focused on all participants who helped to improve paramedical system and reduce suffering of patients.

Authors' contributions

M.R. and R.S. wrote the main manuscript and collect data. K.H. and R.S. did the statistical analysis. D.P. did revisions in the main manuscript. M.K. P.B. N.B. did the training for paramedics and comment on the main manuscript. All authors reviewed the manuscript and agreed with the submission. All authors have read and approved the manuscript.

Funding

No funding was obtained for this study. All research was part of organization operating costs.

Availability of data and materials

The data generated, analysed and used during the current study are available from the corresponding author on reasonable request. The data that support the findings of this study are available from the Emergency Medical Services of Karlovy Vary region, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Emergency Medical Services of Karlovy Vary region.

Declarations

Ethics approval and consent to participate
The study protocol and conduction of the study was approved by Ethical Committee of the Emergency Medical Services of Karlovy Vary Region registered with State Institute for Drug Control of the Czech Republic on 11th of September 2020 under ref. no. ZN/78/ZZSKVK/20. The informed consent was waived and the waiver was approved by the Ethical Committee.
We confirm that all methods were performed in accordance with the relevant guidelines and regulations by including a statement.

Consent for publication
Not applicable.

Competing interests
There are no competing interests of any author.

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Received: 4 October 2021 Accepted: 30 March 2022
Published online: 09 April 2022

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Publisher's Note

18.3 Příloha č. 3 – článek v původním znění Netechnické dovednosti v přednemocniční péči

Peran *et al. BMC Emergency Medicine* (2022) 22:83
https://doi.org/10.1186/s12873-022-00642-4

BMC Emergency Medicine

RESEARCH

Open Access

Non-technical skills in pre-hospital care in the Czech Republic: a prospective multicentric observational study (NTS study)

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Abstract

Background: Non-technical skills (NTS) are important for the proper functioning of emergency medical ambulance crews but have hardly been researched in the conditions of clinical pre-hospital care.

The primary objective of this study, therefore, is to describe the use of NTS in practice. The secondary objective is to compare if the performance of NTS varies according to the type of case.

Methods: In this multicentric observational study the modified Team Emergency Assessment Measure (TEAM) score was used to assess the performed NTS of two or more crews on site. The evaluation consisted of leadership, teamwork and task management, rated by a field supervisor.

The study observations took place in real clinical pre-hospital emergency medical cases when two or more crews were dispatched between October 2019 and August 2020. The sample size was determined by researchers prior to the study to at least 100 evaluated events per each of the three participating emergency medical services.

The results are presented as median and interquartile range. The internal reliability, consistency and validity of test items and results were evaluated. The Kruskal–Wallis test and the post hoc Mann-Whitney U test with Bonferroni correction were used for multiple comparisons of three groups.

Results: A total of 359 events were evaluated. Surprisingly, the median value for all eight items was as high as 3.0 with a similar interquartile range of 1.0. There were no differences observed by case type (CPR vs. TRAUMA vs. MEDICAL) except from item 1. A post hoc analysis revealed that this difference is in favour of a higher rated performance of non-technical skills in CPR.

Conclusions: The overall result of the performance of non-technical skills can be regarded as very good and can serve for further evaluations. The crews achieved better parameters of NTS in leadership in resuscitation situations in comparison with general medical events.

Trial Registration: The study is registered at Clinical Trials under the ID: NCT04503369.

Keywords: Non-technical skills, Pre-hospital care, Emergency medical services, Communication, Situational awareness, Task management, Decision-making, Teamwork, Team leading

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Background

Training of non-technical skills (NTS), including leadership and team training, is used to improve outcomes of cardiopulmonary resuscitation (CPR) [1]. NTS consists of several aspects: (i) teamwork – the work of the team consists of information exchange and coordination of all activities performed, in-team communication is always calm and assertive, and team members support each other; (ii) task management – with the right planning and preparation of individual activities, the likelihood that all standards of care and best practices which will follow increase; (iii) situational awareness – refers primarily to the collection of information, its understanding, and on that basis, prediction of the direction in which the situation will develop; maintaining situational awareness is crucial in order to move towards the right goal; (iv) decision-making – with good situational awareness, one is able to keep in mind all information needed to make the right decision at the right time; in some cases, it is advisable to consult with other team members or to verify their consent to the proposed procedure; (v) communication – a vital tool when working in a team [2]. There is a lack of published studies about the use of NTS in a real medical environment and no articles describing the use of NTS in a real, non-simulated emergency medical services environment [3].

The primary objective of this study is to determine whether Emergency Medical Services (EMS) crews in the Czech Republic are using NTS in practice and, if they do, to describe how. The secondary objective is to compare whether NTS and team performance varies according to the type of case, i.e. resuscitation (CPR), trauma or general medical events.

Methods

Design

A prospective, observational multicentric study of NTS in clinical pre-hospital emergencies was conducted. No randomisation was applied.

Locations

The study took place in three independent organisations in three Czech regions: EMS of Prague, EMS of the Karlovy Vary Region and EMS of the Pilsen Region. The total population of these three regions is approx. 2.2 million [4] with approx. 250,000 emergency cases per year [5]. The data from real clinical events was collected between October 2019 and August 2020.

Eligible criteria

All EMS cases in the Czech Republic in which pre-hospital care was provided by two or more crews (at least four crew members) and the field supervisor were available for observation. The EMS is organised by the regional government as a rendezvous system – advanced care ambulance with paramedic and emergency medical technician and rapid response vehicle with emergency medical technician (or paramedic) and physician on board. Those units can be supported by a field supervisor in all three regions.

Only those cases where two or more ambulance units/crews met with the presence of the field supervisor were observed and included in the study.

In all eligible events, the date and time, the number of crews working in the field (two, three or more), the type of event (CPR, Trauma and Medical, i.e. general medicine emergency events), the name of the field supervisor evaluating the event and the location of the EMS were recorded (Fig. 1).

Exclusion criteria

All emergency cases with only one crew or events without the presence of the field supervisor were excluded, as well as all cases without complete forms.

Outcome measures

Adaptation of the team emergency assessment measure

The modified and simplified Team Emergency Assessment Measure questionnaire (TEAM) was used in this study (Fig. 1). The creation and validation of this tool is described elsewhere and its validation was not part of this study [6–11]. The TEAM was modified for this study as follows: items one through six, i.e. (1) the team leader let the team know what was expected of them through direction and command, (2) the team leader maintained a global perspective, (3) the team communicated effectively, (4) the team worked together to complete tasks in a timely manner, (5) the team acted with composure and control and (6) team morale was positive, all remained unchanged. Item 7 (the team adapted to changing situations) and item 8 (the team monitored and reassessed the situation) were merged into one item, as were items 9 (the team anticipated potential actions) and 10 (the team prioritised tasks). Item 11 (the team followed approved standards/guidelines) was not used, nor was item 12 (the global score) to simplify the field evaluation in the pre-hospital setting. Moreover this modification has been used in the past to evaluate NTS in simulated scenarios [12], and was therefore well known to researchers and field supervisors.

Each of eight TEAM items were rated using a five-point scale (range 0–4; 0 never / hardly ever, 1 seldom, 2 about as often as not, 3 often, 4 always / nearly always) and covered three categories – leadership, teamwork and task management – the same way as the original TEAM [8]. The total score was calculated as the sum of the values of the eight items and used for further statistical interpretations.

Twenty field supervisors (EMS of Prague, $n = 5$; EMS of the Karlovy Vary Region, $n = 6$; EMS of the Pilsen Region,

Tracking form of team non-technical skills (TEAM)

Date: **Time:** **Field supervisor No.:**

Crews on scene: ☐ **1 paramedic crew + 1 physician crew**

☐ **2 paramedic crews + 1 physician crew**

☐ **more**

Type of event: ☐ CPR ☐ TRAUMA ☐ MEDICAL

Note:

	never / hardly ever	*seldom*	*about as often as not*	*very often*	*always / nearly always*
Item 1: The team leader let the team know what was expected of them through direction and command					
Item 2: The team leader maintained a global perspective					
Item 3: The team communicated effectively					
Item 4: The team worked together to complete tasks in a timely manner					
Item 5: The team acted with composure and control					
Item 6: The team morale was positive					
Item 7: The team adapted to changing situations, monitored and reassessed the situation					
Item 8: The team anticipated potential actions and prioritized tasks					

Fig. 1 Modified Team Emergency Assessment Measure questionnaire (TEAM). For each item of TEAM questionnaire the rating of presented performance of non-technical skill was noted and subsequently converted to a numeric value and recorded to the final dataset: never/hardly ever = 0; seldom = 1; about as often as not = 2; very often = 3; always/nearly always = 4

$n = 9$) underwent a standardised e-learning course on the use of the modified TEAM score before the study began. At the end of the e-learning course, each participating field supervisor had to evaluate video recordings of two simulated clinical scenarios (numbered one and two) with actors for further evaluation of inter-rater variability of field supervisors assessments.

Subgroup analysis

This study compared the results of observations between subgroups of cardiopulmonary resuscitation (CPR – defined by the occurrence of cardiac arrest with ongoing CPR on scene), traumatic (TRAUMA – defined by the occurrence of any injury) and general medical events (MEDICAL – defined by any other non-traumatic, non-CPR but general medical situations, including paediatric cases).

Statistical analysis

Baseline characteristics are reported as numbers and percentages. The results of individual items and the total score of modified TEAM questionnaires are presented as median and interquartile range. Internal reliability, consistency and validity were evaluated through inter-item correlation and Cronbach's alpha coefficient and item to total correlation [13]. Inter-rater reliability was assessed with intraclass correlation coefficient (ICC) of evaluation of the two different simulated scenarios (video recordings) [14].

The nonparametric Kruskal–Wallis test was used to compare modified TEAM scores among three presented subgroups, with $p < 0.05$ considered as significant. The post hoc Mann-Whitney U test with Bonferroni correction was used for multiple comparisons.

The sample size was not calculated but was determined by researchers prior to the study to at least 100 evaluated events per each participating emergency medical services.

The data were collected and basic calculations performed in Excel (Microsoft, USA). Statistical software *STATISTICA* 7.0 (StatSoft, USA) was used for statistical analyses and calculation. The ICC calculation software Mangold, Pascal (2018), based on Wirtz & Caspar 2002, (Germany) was used to calculate the adjusted average scores, assuming no interaction effect was present.

Reliability, consistency and validity of testing of modified TEAM score

The inter-rater variability assessed by ICC was 0.958 for e-learning scenario number 1 and 0.701 for e-learning scenario number 2. Inter-item correlation for items 1–8 varied from 0.53 to 0.78, with average inter-item correlation 0.63. Cronbach's alpha coefficient of the final dataset was 0.93 and item-total correlations varied from 0.79–0.87.

Results

A total of 359 events were evaluated in the study after three events were excluded due to incomplete data (Fig. 2). The case types were represented differently between the three different EMS: medical events were the most common category in the EMS of the Karlovy Vary Region, but hardly seen in the Prague EMS, and in the Pilsen Region the categories were more evenly distributed. However, these differences were no longer evident in the total number of events monitored (CPR, $n = 110$ vs. TRAUMA, $n = 122$ vs. MEDICAL, $n = 127$). The most frequently evaluated events were when two ambulances intervened, i.e. with four crew members on the spot ($n = 317$; 88%) (Table 1).

Results of the overall "modified TEAM SCORE"

Monitoring using a modified TEAM score for the whole set of events showed their high use of non-technical skills. Surprisingly, the median value for all eight items was 3.0 with a similar interquartile range. No major shortcomings or reductions in the values of any of the

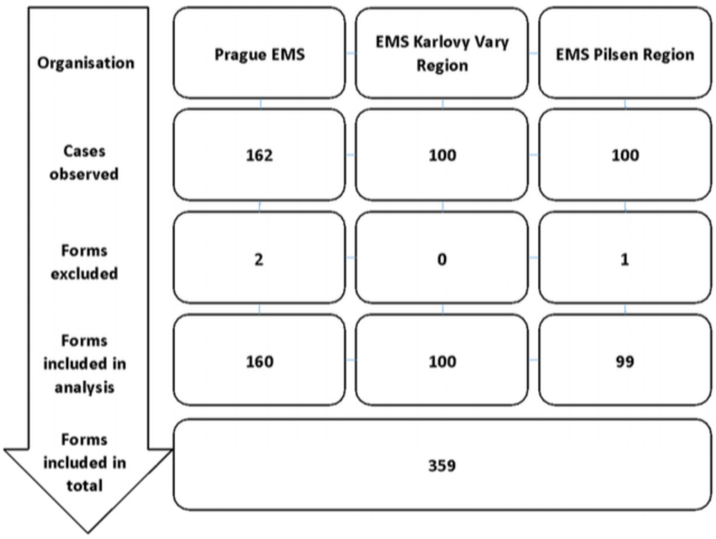

Fig. 2 Study flow diagram

Table 1 Characteristics of events

	Prague EMS ($n=160$)	EMS of Karlovy Vary Region ($n=100$)	EMS of Pilsen Region ($n=99$)	TOTAL ($n=359$)
Event type:				
CPR	72 (45%)	11 (11%)	27 (27%)	110 (31%)
Trauma	84 (53%)	8 (8%)	30 (30%)	122 (34%)
Medical	4 (2%)	81 (81%)	42 (43%)	127 (35%)
Number of crews:				
Two	142 (88%)	99 (99%)	76 (77%)	317 (88%)
Three	12 (8%)	1 (1%)	16 (16%)	29 (8%)
More	6 (4%)	0	7 (7%)	13 (4%)

Data are presented as number of cases and percentage (if appropriate); *CPR* Cases of cardiac arrest with ongoing cardiopulmonary resuscitation, $n=$ number of cases

One ambulance crew means two members of the crew either with a physician and an emergency medical technician/paramedic (the physician crew) or two members of the crew without a physician (the paramedic crew)

skills expressed in the individual items were observed. The overall modified TEAM ratings including total score are presented in detail in Table 2.

Results of the "modified TEAM score" by type of case

The presented data were very similar when comparing the modified TEAM score by case type (CPR vs. TRAUMA vs. MEDICAL). The Only significant difference was observed in item 1 (The team leader let the team know what was expected of them through direction and command) H (2; 359) = 7.64, $p = 0.02$. A post hoc analysis revealed that this difference is in favour of a higher rated performance of non-technical skills in CPR than in MEDICAL events: U (NCPR = 110, NMEDICAL = 127) = 5627, Z = − 257,990, $p = 0.0099$, and none of the other pairwise comparisons were significant after Bonferroni adjustment (all $p > 0.17$). Similarly, despite tendency to better results in item 4 (The team worked together to complete tasks in a timely manner; $p = 0.06$) and item 5 (The team acted with composure and control; $p = 0.09$) this result did not reach statistical significance and therefore no post hoc multiple comparisons analysis was performed. There were no differences observed among other items and total score (Table 3).

Discussion

The results showed high use of the NTS on an average level and there was no difference observed among the subgroups of different medical conditions.

So far, similar results were published only from the hospital environment or simulations or clinical situations with a focus on one part of the non-technical skills or during events of out-of-hospital cardiac arrest only [6, 15–17]. The presented data are comparable in terms of consistency and reliability, but also in terms of the values

Table 2 Overall modified TEAM rating outcomes

	Item statistics	
	Median (IQR)	Observed range
Item 1: The team leader let the team know what was expected of them through direction and command	3.0 (2.0–3.0)	0–4
Item 2: The team leader maintained a global perspective	3.0 (2.0–3.0)	0–4
Item 3: The team communicated effectively	3.0 (2.0–3.0)	0–4
Item 4: The team worked together to complete tasks in a timely manner	3.0 (2.0–3.0)	0–4
Item 5: The team acted with composure and control	3.0 (2.0–3.0)	0–4
Item 6: Team morale was positive	3.0 (2.0–4.0)	0–4
Item 7: The team adapted to changing situations, monitored and reassessed the situation	3.0 (2.0–3.0)	0–4
Item 8: The team anticipated potential actions and prioritised tasks	3.0 (2.0–3.0)	0–4
Total score	23.0 (19–27)	

Data are presented as median and interquartile range (IQR; 25th percentile to 75th percentile); *p* values are presented for item-test (item-total) correlations. TEAM: Team Emergency Assessment Measure with subsequent ratings of presented performance of non-technical skill: 0 = never / hardly ever; 1 = seldom; 2 = about as often as not; 3 = very often; 4 = always / nearly always

Table 3 Comparison of modified TEAM score by case type

	CPR ($n=110$)	TRAUMA ($n=122$)	MEDICAL ($n=127$)	
Item 1: The team leader let the team know what was expected of them through direction and command	3.0 (2.0–4.0)*	3.0 (2.0–3.0)	3.0 (2.0–3.0)*	$p=0.02$
Item 2: The team leader maintained a global perspective	3.0 (2.0–3.0)	3.0 (2.0–3.8)	3.0 (2.0–3.0)	$p=0.32$
Item 3: The team communicated effectively	3.0 (2.0–3.0)	3.0 (2.0–3.0)	3.0 (2.0–3.0)	$p=0.70$
Item 4: The team worked together to complete tasks in a timely manner	3.0 (3.0–3.0)	3.0 (2.0–3.0)	3.0 (2.5–3.0)	$p=0.06$
Item 5: The team acted with composure and control	3.0 (2.0–4.0)	3.0 (2.0–3.0)	3.0 (3.0–4.0)	$p=0.09$
Item 6: Team morale was positive	3.0 (2.0–4.0)	3.0 (2.0–4.0)	3.0 (2.0–3.0)	$p=0.62$
Item 7: The team adapted to changing situations, monitored and reassessed the situation	3.0 (2.0–4.0)	3.0 (2.0–3.0)	3.0 (3.0–3.0)	$p=0.33$
Item 8: The team anticipated potential actions and prioritised tasks	3.0 (2.0–3.0)	3.0 (2.0–3.0)	3.0 (3.0–3.0)	$p=0.10$
Total score	24.0 (19.3–28.0)	22.5 (17.3–27.0)	23.0 (20.0–26.0)	$p=0.37$

Data are presented as median and interquartile range (25th percentile to 75th percentile); *p* values are presented for Kruskal Wallis test; * indicates the significant difference between marked subgroups in pairwise comparisons by Mann Whitney U test with Bonferroni correction; CPR Cases of cardiac arrest with ongoing cardiopulmonary resuscitation, $n=$ Number of cases

of the results with the original work, and sufficient data consistency and interrater variability was observed, calculated and published [7–11, 16, 18]. The research team used the complete TEAM form for pilot field observations [12]. However, based on the pilot findings, the researchers used a simplified form for field supervisors to work in pre-hospital care. In this study we evaluated the situation on the spot, not later, for example from a video recording [17].

This baseline characteristic of NTS obtained from three independent emergency medical services organisations from different regions in the Czech Republic (from the urban region of the capital, rural and mountainous areas, and from a region where urban and rural characteristics of pre-hospital care are combined) provides awareness of the starting level of staff who have not yet been trained in non-technical skills. The specific reason for the study was not to monitor the clinical performance of the provided care, but to focus on NTS. We did not focus on the correlation between non-technical skills performance and clinical outcome.

From the outset, there was no intention to compare individual EMS but to create a suitable case mix, which could correspond with the global spectrum in pre-hospital emergency care in the Czech Republic. The best results were observed especially in CPR, mainly due to significantly better leadership. CPR is “strictly” algorithm-driven, and thus it might be easier for the team leader to instruct the crew members and for team members to follow. Our results that are completely different from those of a recently published study of 114 cases of hospital cardiac arrest, where the leadership was evaluated as the worst [17]. This situation can be partly explained by the fact that the most common training, where aspects of NTS and leadership are also explained, are the Advanced Life Support courses of the European Resuscitation Council, which are widespread in the Czech Republic. This result may also indicate that the focus on the standardised approach is also needed in other fields like trauma and general medical care. Except for CPR, other events observed in the study had very different clinical characteristics and the main goal was to evaluate the aspects of NTS in the interplay of multiple field teams rather than the overall competence. However, the authors are aware that the evidence indicates that checklists tend to overlook the more holistic components of clinical competence, suggesting that global ratings of performance are appropriate [11, 19, 20]. In this context, there is the question of how the scale is set in the validated TEAM score and whether differences in team performance or algorithm application are being revealed. So far, most of the works for individual items report an average score or median around 3 and it is very rarely published whether the level of NTS measured by TEAM score correlates with clinical outcome. In this study, the non-technical skills scale for trauma (T-NOTECHS) [21, 22] or other teamwork assessment measures was not used despite NTS being evaluated in the subgroup of trauma patients. This was mainly to have only one tool for evaluation and the TEAM tool is also highly effective for assessing trauma [11].

Limitations

When adapting the TEAM forms for this study, the researchers merged some TEAM items and omitted the global score as set by Cooper et al. mainly to simplify the evaluation and focus purely on individual aspects of NTS in real clinical field work in a clinically dynamic environment.

As TEAM can be regarded as a proven method, only a data consistency check was performed prior to statistical evaluation. Interrater variability was determined by evaluating the observer's video scenarios and not to a certain proportion of actual field cases, where 10% of cases were considered normal and was done in the original validation study [8]. This was not feasible in a multicentric field study due to logistical reasons. The relatively high number of field supervisors ($n = 20$) could be regarded as a limitation, but their training in TEAM evaluation was extensive and resulted in low interrater variability, which had been checked and proved [11, 23].

A major limitation of this study is that no sample calculation was performed prior to the start of the study. It was only decided to obtain 100 measurements from each participating EMS. This shortcoming in the performed power analysis coupled with the above-mentioned ambiguities in the stratification of the TEAM score scale may cause some uncertainty in the presentation of the results. For now, it is necessary to take these results as a pilot and to follow up the research of other issues such as the correlation of NTS and clinical outcomes, learning effects or standardisation of algorithms.

Conclusions

The overall result of non-technical skills performance can be regarded as very good and can serve for further evaluations. There was no significant difference observed according to the medical conditions of the events except for better leadership in CPR.

Abbreviations

CPR: Cardiopulmonary resuscitation; NTS: Non-technical skills; TEAM: Team Emergency Assessment Measure questionnaire; EMS: Emergency Medical Services; ICC: Intraclass correlation coefficient.

Acknowledgements

The authors would like to thank all the supervisors who participated in the data collection and the management of all organisations that took part in the study.

Authors' contributions

DP: Conceptualisation, Methodology, Formal Analysis, Resources, Writing – original draft; RS: Methodology, Formal Analysis, Validation, Writing – original draft; JV: Conceptualisation, Investigation, Writing – Reviewing and Editing; IK: Investigation, Writing – Reviewing and Editing; JP: Conceptualisation, Methodology, Writing – original draft; MR: Formal Analysis, Validation, Writing – Reviewing and Editing; NB: Investigation, Writing – Reviewing and Editing; PChC: Conceptualisation, Methodology, Supervision, Writing – Reviewing and Editing. The authors read and approved the final manuscript.

Funding

No funding. This work received no specific grant from any funding agency in the public, commercial or non-profit sectors.

Availability of data and materials

All data generated or analysed during this study are included in this published article.

The baseline dataset used and analysed during the current study is available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the ethics committee of the EMS of the Karlovy Vary Region under Approval Number: 374/19/ZZSKVK on 7 January 2019, before the study started. All participating field supervisors consented to the collection of data from the field as an extension of their routine work on a voluntary basis. The crew members were not aware of the study and the purpose and type of data collection by the field supervisors. Observations were made in accordance with the laws of the Czech Republic. No patient rights were affected, all observations were anonymised, and no patient or employee data were collected at any stage of the study. No signed informed consents were required.

The study is registered at Clinical Trials under the ID: NCT04503369.

Consent for publication

Not applicable.

Competing interests

The authors declare no conflicts of interest.

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Received: 16 January 2022 Accepted: 28 April 2022
Published online: 13 May 2022

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18.4 Příloha č. 4 – článek v původním znění Rozšířená resuscitace dospělých v podání dvoučlenných výjezdových skupin záchranné služby

RESUSCITATION PLUS 18 (2024) 100661

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Review

Efficiency of two-member crews in delivering prehospital advanced life support cardiopulmonary resuscitation: A scoping review

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Abstract

Background: Advanced Life Support (ALS) during cardiopulmonary resuscitation (CPR) for out-of-hospital cardiac arrest (OHCA) is frequently administered by two-member crews. However, ALS CPR is mostly designed for larger crews, and the feasibility and efficacy of implementing ALS guidelines for only two rescuers remain unclear.

Objective: This scoping review aims to examine the existing evidence and identify knowledge gaps in the efficiency of pre-hospital ALS CPR performed by two-member teams.

Design: A comprehensive search was undertaken across the following databases: PubMed, Web of Science, SCOPUS, Cochrane Library Trials, and ClinicalTrials.gov. The search covered publications in English or German from January 1, 2005, to November 30, 2023. The review included studies that focused on ALS CPR procedures carried out by two-member teams in adult patients in either simulated or clinical settings.

Results: A total of 22 articles were included in the qualitative synthesis. Seven topics in two-person prehospital ALS/CPR delivery were identified: 1) effect of team configuration on clinical outcome and CPR quality, 2) early airway management and ventilation techniques, 3) mechanical chest compressions, 4) prefilled syringes, 5) additional equipment, 6) adaptation of recommended ALS/CPR protocols, and 7) human factors.

Conclusion: There is a lack of comprehensive data regarding the adaptation of the recommended ALS algorithm in CPR for two-member crews. Although simulation studies indicate potential benefits arising from the employment of mechanical chest compression devices, prefilled syringes, and automation-assisted protocols, the current evidence is too limited to support specific modifications to existing guidelines.

Keywords: Advanced life support, Cardiopulmonary resuscitation, Out-of-hospital cardiac arrest, Two-member team, Crew size, Emergency medical service

Introduction

The early start of high-quality Advanced Life Support (ALS) has been shown to increase the incidence of return of spontaneous circulation (ROSC) and survival to hospital discharge after out-of-hospital cardiac arrest (OHCA).[1] It is often administered by two-member ambulance crews as the first responders in diverse pre-hospital emergency care (PHEC) systems.[2] However, for such small teams, adhering to high-performance ALS protocols during the initial stages of CPR presents a significant challenge[3] and, for example, ALS section of European Resuscitation Council (ERC) Guidelines for Resuscitation is typically designed with unspecified, though usually larger, teams in mind who can share the workload.[4]

The ALS algorithm in ERC Guidelines differentiates its treatment priorities based on whether the OHCA presents with a shockable or

Abbreviations: AED, automated external defibrillator, ALS, advanced life support, BLS, basic life support, BMV, bag mask ventilation, CCF, chest compression fraction, CPR, cardiopulmonary resuscitation, EMS, emergency medical services, HEMS, helicopter emergency medical services, LMA, laryngeal mask airway, OHCA, out-of-hospital cardiac arrest, PHEC, pre-hospital emergency care, ROSC, return of spontaneous circulation

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https://doi.org/10.1016/j.resplu.2024.100661

Received 4 March 2024; Received in revised form 29 April 2024; Accepted 6 May 2024

non-shockable initial rhythm.[4] For a two-person team, significant difficulties arise in applying ALS during CPR mostly due to advanced airway management and drug preparation and administration.[3] Given that the ALS algorithm in the ERC Guidelines[4] comprises several procedures, it becomes challenging for a two-person team to prioritize actions, since performing multiple tasks simultaneously, as larger teams do, is difficult.

Previous simulation studies have examined the feasibility of adapting the ALS algorithm for CPR delivered by two-person teams in helicopter emergency medical services (HEMS)[5] and military settings.[6] There is also sporadic data on the use of mechanical chest compression devices[7,8] and supraglottic airway devices [9,10] during ALS CPR by two member crew, but these interventions were not primarily intended to free the hands of the pair of rescuers. Also, other aspects such as human factors[11] including equipment ergonomics[12] or automation-assisted protocols[13] are understudied, as trials tend to focus more on patient-centred outcomes.[14,15] However, despite its practical importance in the initial CPR phase until a larger crew has gathered on-site, the implementation of ALS protocols[4] for two professional rescuers is not covered in current research directions.[16]

It could be hypothesized that in pre-hospital emergency settings where human resources are limited, modifications to ALS guidelines aimed at freeing the hands of rescuers could improve the quality of ALS CPR and, potentially, patient outcomes.

The aim of this scoping review is to synthetise and critically appraise the existing evidence in the field and also identify knowledge gaps in research on ALS provided by two-member teams.

Methods

The scoping review was conducted in accordance with the Joanna Briggs Institute methodology for scoping reviews[17] and adhered to the Preferred Reporting Items for Systematic Reviews and Meta-analysis Protocols extension for Scoping Reviews (PRISMA-ScR).[18] The objectives, inclusion criteria, and methods were defined and detailed a priori in a protocol. This protocol was collaboratively revised by the academic research team members (DP, MK, MR, RS) and prospectively registered with the Open Science Framework (OSF) on September 1, 2023.[19] No ethical approval was required for this study.

Studies published between January 1, 2005, and November 30, 2023, were included as the resuscitation guidelines stated the 30 compressions to 2 rescue breaths ratio in the year 2005. The selection criteria for the studies were determined using PICOS framework, formulated as follows. **Population**: Two-member teams performing ALS CPR in out-of-hospital setting. **Intervention:** Any specific strategy to deliver ALS CPR by two-member teams to adult patients (18 years and older, adult patient simulations) in cardiac arrest with both shockable and non-shockable rhythms. **Comparison:** Any type of comparisons was assessed, including no comparison. **Outcome:** Any type of outcomes was assessed (clinical or simulated). **Study design**: No limitations to type of research (qualitative or quantitative), study design (randomised, observational, retrospective) or setting (clinical or simulated).

Excluded from this review were studies focusing on cardiac arrest in children, studies evaluating very specific circumstances (e.g., CPR during patient transportation, aviation or spaceflight, maritime settings, sports events, etc.) and studies with outcomes or study focus other than performing ALS procedures. While case reports, letters to the editor, correspondences, editorials, conference abstracts, systematic reviews, guidelines, and trial protocols were referenced for secondary sources, they were not included in the analysis.

The initial search was conducted in PubMed and Web of Science to establish keywords and a search strategy. Subsequent searches encompassed databases such as PubMed, Web of Science, Scopus, and the Cochrane Library Trials, along with the ClinicalTrials.gov register to identify potentially relevant papers, including published trial protocols. A secondary reference search was conducted from all the selected papers. The full search strategy for these databases, as revised by a university librarian, is presented in Appendix A. The results of the database search were exported to Zotero (an open-source research tool, Corporation for Digital Scholarship, USA, zotero.org) for duplicate removal.

Titles and abstracts were independently screened by two reviewers (MK and RS) against the inclusion and exclusion criteria (agreement in 93.1%, Cohen's kappa 0.76). If there was no agreement on inclusion of selected articles, discrepancies were resolved through discussion with a third reviewer (DP) and frequently needed examination of full-texts. Subsequently, full-text articles were downloaded and thoroughly assessed by the same reviewers. Reasons for exclusion at the full-text assessment stage (Cohen's kappa 1.0) included the provision of CPR only within BLS, more than only two crew members, or data deemed irrelevant by the reviewers. Details of the data extraction process can be found in Appendix B. Outcomes were not pre-defined, and extracted data included information about study populations, methods, and outcomes relevant to the scoping review.

Content analysis from found sources of evidence was performed. The extracted data was subsequently grouped into categories depending on the topic. A narrative approach was employed to address the research question.

Results

Selection of sources of evidence

The initial search yielded 216 articles. Following the removal of duplicates and screening of abstracts, 33 full-text articles were assessed for eligibility with 22 full-text papers retrieved for the final analysis. The selection process is detailed in the PRISMA-ScR flow diagram (Fig. 1).

Characteristics of sources of evidence

The included studies predominantly featured simulation data ($n = 21$) alongside one pre-hospital clinical study ($n = 1$). Quantitative methods were employed in nineteen articles, while three utilized mixed methods. None of the studies used solely qualitative methods. The designs and main subjects of these studies are summarized in Table 1. Twelve studies explicitly stated a focus on two-member teams in their titles or objectives (marked with asterisk in Table 1). The remaining studies incorporated two-member teams as part of their methodology to address various objectives. Detailed information on each article, including the rescuer population, sample size (rescuers or patients), context, relevant outcomes, and key findings, is summarized in Table 2.

Synthesis of results

The studies were classified into seven coding categories based on content analysis, with some studies fitting into multiple categories. These categories were further divided into subgroups (Table 3).

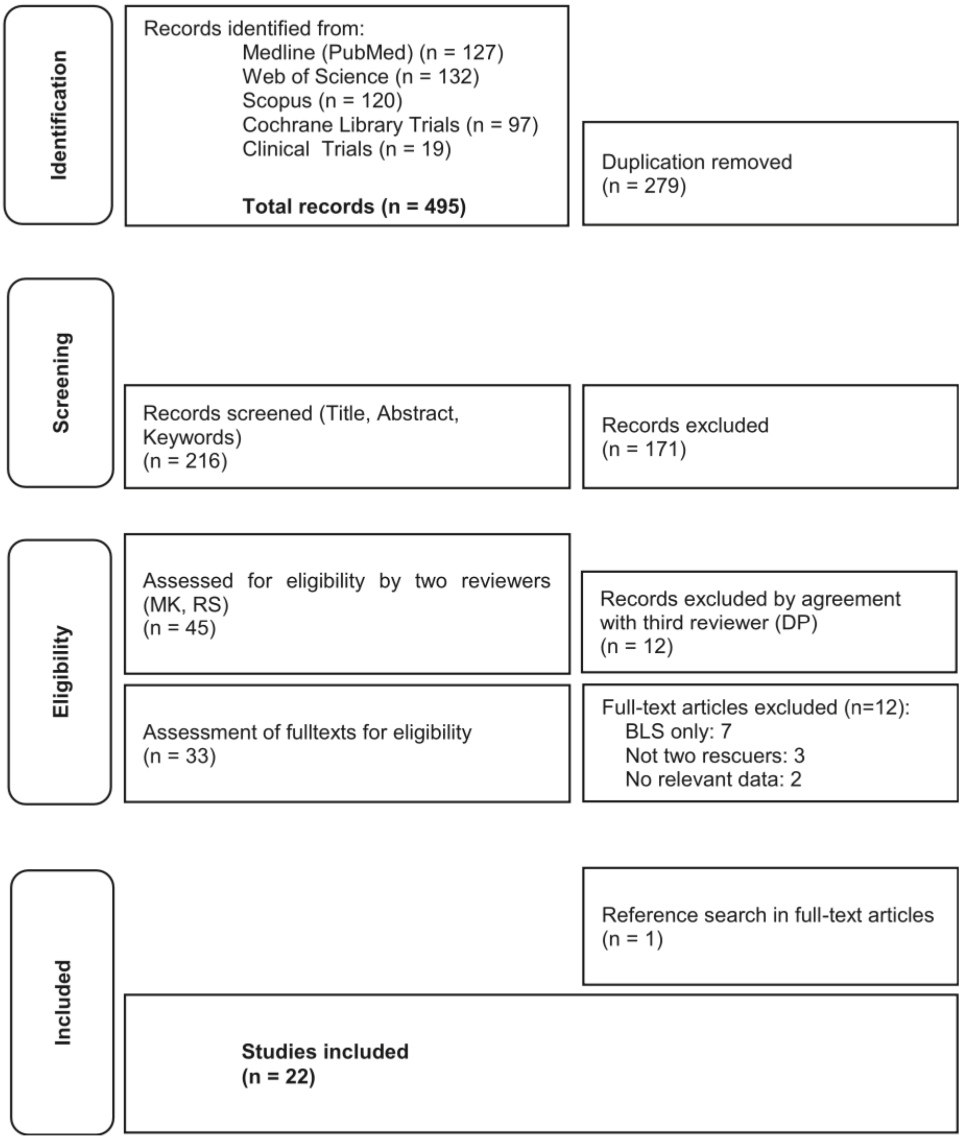

Fig. 1 – PRISMA Flow Diagram for the scoping review proces.

Team configuration and CPR quality

One and five studies investigated **the effect of ALS team configuration on clinical outcome and quality of CPR respectively.**[14,20–24] Five of these examined the effects of team size. [14,20–23] One retrospective clinical study involving 10 057 OHCA patients found that having more than two paramedics at the scene did not improve survival to hospital discharge (2 paramedics – 8.7%, 3 paramedics – 8.7%, ≥4 paramedics – 8.4%, $p = 0.88$).[14] Several simulation studies demonstrated superior CPR quality (chest compression quality and fraction) in teams larger than two, along with a more efficient achievement of critical CPR endpoints such as rhythm recognition, adrenaline administration, and tracheal intubation.[20–22] No significant difference in the no-flow fraction was observed between teams of two, three, and four paramedic students in one simulated ALS/CPR study.[23] One study comparing team compositions found that teams of two paramedics were more prone to errors and generally slower in most interventions (except for tracheal intubation), compared to paramedic-emergency medical technician (EMT) teams.[24]

Early airway management and ventilation

Another five simulation studies examined **the efficacy of early airway management and patient ventilation** by two-member crews.[5,6,9,25,26] In a cross over study of two member teams the asynchronous patient ventilation during continuous chest compressions with a LMA inserted by a physician resulted in higher tidal volumes and ventilation frequencies than recommended compared to asynchronous face mask ventilation.[25] Other four works found were feasibility studies of securing the airway in a two-member team without

Table 1 – Characteristics of sources evidence.

Author and year	Country	Design	Method	Type	Main topic
Asselin (2018)[11]	USA	Randomized, controlled	Mixed methods	Simulation	Workload and physical exertion
Bayley (2008)[24] *	USA	Two group design	Quantitative	Simulation	Team configuration
Brucke (2007)[5] *	Germany	Feasibility study	Quantitative	Simulation	Protocol adaptation
Choi (2016)[13]	USA	Randomized, controlled	Quantitative	Simulation	Protocol adaptation
Dundar (2021)[25]	Turkey	Randomized, cross-over	Quantitative	Simulation	Airway management
Eschmann (2009)[14] *	USA	Retrospective observation	Quantitative	Clinical	Team configuration
Guyette (2006)[9]	USA	Feasibility study	Quantitative	Simulation	Protocol adaptation
Harari (2020)[12]	Israel	Experiment, observation	Mixed methods	Simulation	Workload and physical exertion
Kern (2010)[31]	USA	Randomized, controlled	Quantitative	Simulation	Protocol adaptation
Klosiewicsz (2020A)[7] *	Poland	Randomized, cross-over	Quantitative	Simulation	Mechanical CC
Klosiewicsz (2020B)[8] *	Poland	Randomized, cross-over	Quantitative	Simulation	Mechanical CC
Krzyzanowski (2021)[21] *	Poland	Randomized, controlled	Quantitative	Simulation	Team configuration
Martin-Gill (2010)[23] *	USA	Randomized, controlled	Quantitative	Simulation	Team configuration
Nitzschke (2017)[32]	Germany	Randomized, controlled	Quantitative	Simulation	Additional equipment
Robak (2020)[27] *	Poland	Randomized, controlled	Quantitative	Simulation	Prefilled syringes
Robakowska (2022)[22] *	Poland	Randomized, controlled	Quantitative	Simulation	Team configuration
Siebers (2009)[26]	Germany	Feasibility study	Quantitative	Simulation	Airway management
Tsai (2020)[20] *	Taiwan	Randomized, multiple group	Mixed methods	Simulation	Team configuration
Ventzke (2011)[6] *	Germany	Feasibility, two group	Quantitative	Simulation	Airway management
Zalewski (2020A)[28]	Poland	Randomized, cross-over	Quantitative	Simulation	Airway management
Zalewski (2020B)[30]	Poland	Randomized, cross-over	Quantitative	Simulation	Prefilled syringes
Zalewski (2020C)[29] *	Poland	Randomized, cross-over	Quantitative	Simulation	Prefilled syringes

Legend: Studies in which the evaluation of two-member teams was declared in the title or the study aims are marked with an asterisk. CC, chest compressions.

further comparison.[5,6,9,26] Basic EMTs achieved a 78% success rate in LMA insertion during CPR in one feasibility study.[9] Another feasibility study showed that paramedics and physicians secured airways with a laryngeal tube in an average of 17 s with a 75% success rate on the first attempt and 100% on the second attempt.[6] Another study recorded tracheal intubation attempts by EMTs and paramedics, noting an average duration of 82 ± 27 s and a 70% success rate on the first attempt, while the no-flow fraction was high (41.7 ± 6.7%).[26] A feasibility study on HEMS teams tested a modified ALS/CPR algorithm focusing on early tracheal intubation before rhythm check, finding it feasible with acceptable chest compression and ventilation quality, though the time to first shock was not mentioned.[5]

Mechanical chest compressions

Three simulation studies investigated **the use of mechanical chest compression devices** by two-member teams.[7,8,13] An experimental automation-assisted ALS/CPR protocol study showed improved chest compression depth and a reduction in inadequate chest compressions.[13] Two simulation studies found that mechanical chest compressions enhanced the quality of chest compressions and improved adherence to ALS guidelines, with the earlier achievement of resuscitation goals.[7,8]

Pre-filled syringes

Three simulation studies in two-member ALS teams focused on the effect of using **pre-filled syringes** with medication.[27–29] All three studies reported reduced time to adrenaline administration[27–29], while two noted a shorter time to intravenous or intraosseous access.[27,29] One study found a higher chest compression fraction and quicker airway management.[28]

Additional equipment

Four simulation studies evaluated **the use of additional equipment** in two-member teams of rescuers.[9,30–32] One study found that adhesive defibrillation electrodes improved chest compression quality and electrotherapy application speed.[30] A feasibility study demonstrated a 94% first-pass success rate of intraosseous access by EMTs.[9] Another study indicated less variance in chest compression and ventilation rates with metronome use.[31] A prototype resuscitation assist device (AED, ventilator, and ALS instructions) did not overall improve hands-off time but negatively impacted CPR quality in highly trained two-provider teams.[32]

Adaptations of protocol

Two simulation studies explored **adaptations to the ALS/CPR protocol** in case of two ALS providers.[11,13] An experimental automation-assisted, goal-directed OHCA protocol (including mechanical chest compressions, AED, ventilator, supraglottic airway devices, and early intraosseous access) used by EMTs resulted in improved chest compression depth, higher minute ventilation, and more appropriate medication administration.[13] This protocol also reduced physical exertion and perceived workload in another study.[11]

Workload and physical exertion

A simulation study focusing on **workload and physical exertion** in two-member crew found that the placement of the equipment bag around the patient during simulated OHCA affected CPR quality, work efficiency, effort, and biomechanical loads.[12]

Discussion

This scoping review reveals a significant shortfall in the evidence required to develop a comprehensive ALS protocol tailored to the unique dynamics of two-member (ambulance) crews. The evidence found is not sufficiently robust to formulate recommendations for informing training, protocols, or equipment choices. Published studies suggest that certain interventions, such as the implementation

Table 2 – Results of individual source of evidence.

Author and year of publication	Population and sample size (rescuers / patients)	Context	Outcomes relevant to the review	Findings
Asselin (2018)[11]	EMTs (*n* = 40)	Experimental protocol	Physical exertion and workload	Experimental approach: reduced physician exertion and lower workload
Bayley (2008)[24]	EMTs and paramedics (*n* = 60)	ALS/CPR by different crew configurations	Errors, time to critical interventions, compliance with continuous CPR	Paramedic-paramedic crews: significantly more errors than paramedic-EMT crews. Most interventions not performed more rapidly with the exception of TI.
Brucke (2007)[5]	Physicians and paramedics (*n* = 40)	Early TI during ALS/CPR. Feasibility study.	No-flow time, CC quality	Algorithm with early TI proved feasible in manikin setting.
Choi (2016)[13]	EMTs (*n* = 40)	ALS/CPR using automation assisted protocol	CC quality, defibrillation quality, airway securing, medication.	Automation assisted protocol: improved quality of CCs, ventilation and medication administration.
Dundar (2021)[25]	Physicians (*n* = 92)	LMA versus asynchronous BVM ventilation during ALS/CPR	Primary: Ventilation quality measuresSecondary: CC quality measures	Asynchronous ventilations by BVM compared to asynchronous ventilations by LMA: lower quality of but still sufficient ventilation.
Eschmann (2010)[14]	EMTs and paramedics. (*n* = 10057 patients)	Retrospective database review.	Primary: Survival to hospital dischargeSecondary: ROSC, survival to hospital admission, time to defibrillation	Three or more paramedics in team during OHCA: not associated with improved survival to hospital discharge as compared to crews of two paramedics.
Guyette (2006)[9]	EMTs (*n* = 18)	Advanced resuscitation interventions by EMTs.	Time to critical interventions	EMTs were able to initiate use of LMA and IO access in a simulated cardiac arrest.
Harari (2020)[12]	Paramedics (*n* = 24)	Equipment positioning during ALS/CPR	Quality measures of CPR, work efficiency measures, physiological effects, ergonomic assessments.	Positions of the equipment around the patient during OHCA affect CPR quality and measures of paramedic's work efficiency, effort, and biomechanical loads.
Kern (2010)[31]	EMTs (*n* = 68)	Metronome use during ALS/CPR	CC rate, ventilation rate	Metronome group: significantly better CC rate, less rate variance.
Klosiewicsz (2020A)[7]	Paramedics (*n* = 104)	Mechanical CC during ALS/CPR	CC quality	Use of mechanical CC device increased CC quality measures
Klosiewicsz (2020B)[8]	Paramedics (*n* = 104)	Mechanical CC during ALS/CPR	Intervals between rhythm checks, duration of rhythm check, time to medication	Use of mechanical CC device: improved adherence to ALS protocol and earlier achievement of resuscitation endpoints.
Krzyzanowski (2021)[21]	Paramedics (*n* = 463)	Team size comparison	Time to critical interventions, CC quality measures, medication errors	Three-member teams: faster times to critical interventions, higher CC quality, less medication errors.
Martin-Gill (2010)[23]	Paramedic students (*n* = 40)	Team size comparison	No-flow fraction	No significant difference in no-flow fraction between 2-, 3- and 3-member teams.
Nitzschke (2017)[32]	EMTs and paramedic (*n* = 112)	ALS/CPR using prototype CPR assist device	Primary: Hands-off timeSecondary: CC quality, ventilation quality. Correct medications, time to critical interventions	No difference in the hands-off time when using prototype CPR assist device compared to standard equipment.
Robak (2020)[27]	Paramedics (*n* = 40)	ALS/CPR with pre-filled medication syringes	Time to critical interventions	The use of pre-filled adrenaline syringes: shorter time to intraosseous access, shorter time to adrenaline.
Robakowska (2022)[22]	Paramedics (*n* = 463)	Team size comparison	CC quality, time to critical interventions	3-member teams: critical interventions faster, quality of CC comparable.
Siebers (2009)[26]	EMTs and paramedics (*n* = 104)	Early TI during ALS/CPR	CC interruptions. No-flow time. TI success rate.	Early TI: increased no-flow time, higher TI failure rate by not well-trained personnel.
Tsai (2020)[20]	Paramedics (*n* = 140)	Team size comparison	CC fraction, time to critical interventions, quality of team performance	CC fraction improved as team size increased. Shorter times to critical interventions with larger teams.

(continued on next page)

Table 2 (continued)

Author and year of publication	Population and sample size (rescuers / patients)	Context	Outcomes relevant to the review	Findings
Ventzke (2011)[6]	Physicians and paramedics (*n* = 40)	Early laryngeal tube insertion and over-the-head CC during ALS/CPR	Time to secured airways, CC quality measures, ventilation quality measures	Early use of laryngeal tubus and over-the-head CC were feasible with 2 rescuers.
Zalewski (2020A)[28]	Paramedics (*n* = 200)	ALS/CPR with pre-filled medication syringes	CC quality measures. Time to airway securing.	The use of pre-filled syringes with adrenaline: improved CC quality, shorter time to airway securing.
Zalewski (2020B)[31]	Paramedics (*n* = 200)	ALS/CPR using self-adhesive electrodes	CC quality measures, duration for *peri*-shock pause. Time to airway securing	The use of multifunction pads: improved CC quality, earlier airway securing.
Zalewski (2020C)[29]	Paramedics (*n* = 106)	ALS/CPR with pre-filled medication syringes	Time to critical interventions, CC quality measures	The use of pre-filled syringes with adrenaline and amiodarone: faster achievement of critical interventions, CC quality did not differ.

Legend. CC, chest compressions. EMTs, emergency medical technicians. NFF, no-flow fraction. TI, tracheal intubation.

Table 3 – Coding categories and subgroups.

Effect of team configuration on CPR quality and outcome
Team size
Team composition
Early airway management and ventilation technique
Mechanical chest compressions
Prefilled syringes
Use of additional equipment
Adhesive defibrillation electrodes
Intraosseous access
Metronome use
Prototype CPR assist device
Adaptation of ALS/CPR protocols
Human factors
Workload
Physical exertion

of mechanical chest compressions, the use of pre-filled syringes, and the utilization of an automation-assisted protocol, may enhance the performance of such teams.

Predominantly, the subject has been explored through simulation and feasibility studies, which exhibit considerable methodological heterogeneity. Several themes emerged that could influence the effectiveness and efficiency of ALS CPR performed by two-member ambulance crew in OHCA setting.

Larger crew sizes appear to be less error-prone and more efficient in airway management and overall performance, including CPR quality.[20–23] However, clinical outcomes for OHCA patients treated by two-member crews have only been evaluated in a single retrospective study, which did not detail specific protocols or contributions of first professional responders beyond crew size.[14]

In various simulation studies, thematic areas have been identified that could inform the optimal sequence and interplay of ALS procedures during CPR for maximal performance and adherence to ALS guidelines.

Early airway management remains a contentious issue,[33] but the supraglottic airway devices use appears not to be inferior to tracheal intubation as a method of initial airway management in OHCA.[34–36] Its use may have a positive impact on achieving ROSC, though its effect on other clinical outcomes in OHCA remains uncertain.[37] The ease of inserting a laryngeal mask allows for ergonomic approaches like over-the-head CPR and ventilation.[38]

While continuous compressions and ventilation at a rate of 10 breaths per minute are recommended after securing the airway,[4] the early insertion of laryngeal mask might permit one rescuer to continue with a 30:2 ratio[38] while the other prepares for additional procedures.[4] Future recommendations and studies should distinguish between aspects of airway management in shockable and non-shockable rhythms due to differing priorities, especially regarding the criticality of timely defibrillation.

Mechanical chest compressions, though not routinely recommended, can free up rescuers' hands for other tasks in understaffed conditions and challenging locations. Pre-filled syringes appear practical, but questions about spatial storage, distribution, and color differentiation in ambulances and rescue bags[39] are yet to be resolved. The use of intraosseous access as a universal procedure during OHCA is debatable, but it is a quick and time-saving intervention. The use of disposable electrodes and metronomes in field defibrillators and monitors is currently accepted.[4,16]

Although international ALS CPR guidelines are created through a very careful and rigorous process aimed at assessing patient outcomes, less attention is paid to the deliverability of individual steps under certain conditions.[4,16] No comprehensive work has yet been published that would establish a protocol for a two-member crew, optimizing all major approaches described above in line with current recommendations. Adapting disposable equipment for the two-member crew OHCA ALS CPR is also necessary. Crew training should encompass not only algorithm steps but also movement around the patient. It's clear that a well-trained professional with in-depth procedure knowledge according to their role must proceed in a precisely structured manner.

The data indicates that this is an underexplored issue, despite being a common scenario for the often first-arriving two-member ambulance crew at an OHCA site. However, the clinical recommendations from the presented outcomes are currently weak. Therefore, it is essential to create robust, methodologically sound randomized simulation studies addressing most of the topics mentioned during

ALS CPR, including modifications for shockable and non-shockable OHCA rhythms. These studies could serve as a background for future clinical studies. The research questions of such studies could address the knowledge gaps such as prioritisation of the ALS procedures that are linked with improved outcomes and freeing hands of rescuers, equipment choices and ergonomics during ALS CPR by two-member teams.

Limitations

The chosen time interval from 2005 was selected to align with publications reflecting recommendations similar to current ERC guidelines.[4] To refine our objectives and the potential generalization of findings, articles on CPR in paediatric patients or special circumstances were excluded.

The outcomes of the selected studies were not determined a priori, in accordance with methodological guidance for scoping reviews.[17]

The objectives and methodologies of the identified studies varied. High-quality, detailed qualitative analyses are missing, and no randomized prospective controlled clinical trials with systematic clinical outcome measurements exist.

Not all studies explicitly stated a focus on two-member teams in their titles or objectives. Some studies used two-member teams to test various interventions but did not state the aim to study two-member teams specifically. The heterogeneity of the included studies was significant. Most were simulation studies with varying interventions, currently incomparable and collectively only providing partial insight into the complexity of the issue.

Additionally, all assessed studies were conducted based on recommendations older than the current ones.[4] It is evident that numerous local protocols in emergency medical services worldwide address the two-member crew approach to providing high-quality, protocol-adherent ALS, which cannot be exhaustively traced.

Conclusion

Based on the currently identified evidence, no specific adaptations within the ALS structure for two-member teams responding to OHCA can be recommended. This underscores the need for more comprehensive and robust studies in this area.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT-4, OpenAI in order to improve language and readibility without changing the context. This tool was used after the text was drafted and the authors reviewed and edited the content as needed and take full responsibility for the content of the publication

CRediT authorship contribution statement

Miroslav Keselica: Writing – review & editing, Writing – original draft, Methodology, Investigation. **David Peřan:** Writing – review & editing, Methodology, Investigation. **Metoděj Renza:** Writing – review & editing, Writing – original draft, Investigation. **František Duška:** Writing – review & editing, Supervision, Conceptualization. **David Omáčka:** Writing – review & editing, Methodology, Investigation. **Sebastian Schnaubelt:** Writing – review & editing, Conceptualization. **Ileana Lulic:** Writing – review & editing, Conceptualization. **Roman Sýkora:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: The authors declare that they have no known financial or personal competing interests that could have influenced this work. The research was carried out at the Third Faculty of Medicine of Charles University in Prague and Emergency Medical Services of the Karlovy Vary region. The work has been supported by the institutional support of Charles University, Prague, Czech Republic (Cooperatio – Intensive Care Medicine).

Acknowledgement

The author team expresses gratitude to Dr. Martina Habova, the head of the Center of Scientific Information at the Third Faculty of Medicine, Charles University in Prague, for her corrections and suggestions regarding the search strategy. This article was prepared as part of the 2-Rescuer ALS Task Force of the European Resuscitation Council's ALS Science and Education Committee. The authors express their gratitude to Dr. César Roza Alonso, Dr. Francesc Carmona, Dr. Martin Michalov, Dr. Anatolij Truhlář and Dr. Francesca Verginella for their help and insightful comments.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2024.100661.

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Supplementary Data k článku - Rozšířená resuscitace dospělých v podání dvoučlenných výjezdových skupin záchranné služby

1) Research strategy

1. PubMed

Concept	**Keyword**	**MeSH**
Cardiopulmonary Resuscitation Advanced Life Support	Cardiopulmonary Resuscitation CPR Resuscitation Cardiac arrest Heart arrest Advanced life support ALS Advanced Cardiovascular Life Support ACLS Advanced Resuscitation Procedure*	"Advanced Cardiac Life Support" [Mesh] "Heart Arrest"[Mesh] "Out-of-Hospital Cardiac Arrest"[Mesh] "Cardiopulmonary Resuscitation"[Mesh]
Two-member crew	2 health care professional* # 2 health care provider* # 2 paramedic* # 2 rescuer* Two health care professional* Two healthcare professional* Two paramedic* Two person* Two provider* Two rescuer* Two-man crew* Two-man crew* Two-man team* Two-member team* Two-person crew* Two-person team* Two-rescuer team*	*No MeSH term applicable*

Concept 1 (OR / keywords OR MeSH (if MeSH keyword omitted)
AND
Concept 2 (OR / keywords, # omitted due to inadequate phrase)

Searching in all fields, using MeSH and keywords, tag [Tiab] not used
Limits: Last 18 years (since January 1st 2005)

Advanced search
("Cardiopulmonary Resuscitation"[All Fields] OR "resuscitation"[All Fields] OR "Cardiac arrest"[All Fields] OR "heart arrest"[All Fields] OR "Advanced life support"[All Fields] OR "ALS"[All Fields] OR "Advanced Cardiovascular Life Support"[All Fields] OR "ACLS"[All Fields] OR "advanced resuscitation procedure*"[All Fields] OR ("Advanced Cardiac Life Support"[MeSH Terms] OR "heart arrest"[MeSH Terms] OR "Out-of-Hospital Cardiac Arrest"[MeSH Terms] OR "Cardiopulmonary Resuscitation"[MeSH Terms])) AND ("2 rescuer*"[All Fields] OR "two health care professional*"[All Fields] OR "two paramedic*"[All Fields] OR "two person*"[All Fields] OR "two provider*"[All Fields] OR "two rescuer*"[All Fields] OR "two man crew*"[All Fields] OR "two man team*"[All Fields] OR "two person crew*"[All Fields] OR "two person team*"[All Fields] OR "two rescuer team*"[All Fields])

Conversion of the search strategy to:

2. WEB OF SCIENCE:

Refine to > 2004
(ALL=(cardiopulmonary AND resuscitation) OR ALL=(cpr) OR ALL=(resuscitation) OR ALL=(cardiac AND arrest) OR ALL=(heart AND arrest) OR ALL=(advanced AND life AND support) OR ALL=(als) OR ALL=(advanced AND cardiovascular AND life AND support) OR ALL=(acls) OR ALL=("Advanced Resuscitation Procedure*")) AND (ALL=("2 health care professional*") OR ALL=("2 health care provider*") OR ALL=("2 paramedic*") OR ALL= ("2 rescuer*") OR ALL=("Two healthcare professional*") OR ALL=("Two paramedic*") OR ALL=("Two person*") OR ALL=("Two provider*") OR ALL=("Two rescuer*") OR ALL=("Two-man crew*")OR ALL=(" Two-man team*") OR ALL=("Two-member team*") OR ALL=("Two-person crew*") OR ALL=("Two-person team*") OR ALL=("Two-rescuer team*"))

3. SCOPUS

(TITLE-ABS-KEY (cardiopulmonary AND resuscitation) OR TITLE-ABS-KEY (cpr) OR TITLE-ABS-KEY (resuscitation) OR TITLE-ABS-KEY (cardiac AND arrest) OR TITLE-ABS-KEY (heart AND arrest) OR TITLE-ABS-KEY (advanced AND life AND support) OR TITLE-ABS-KEY (als) OR TITLE-ABS-KEY (advanced AND cardiovascular AND life AND support) OR TITLE-ABS-KEY (acls) OR TITLE-ABS-KEY ("Advanced Resuscitation Procedure*")) AND (TITLE-ABS-KEY ("2 health care professional*") OR TITLE-ABS-KEY ("2 health care provider*") OR TITLE-ABS-KEY ("2 paramedic*") OR TITLE-ABS-KEY ("2 rescuer*") OR TITLE-ABS-KEY ("Two healthcare professional*") OR TITLE-ABS-KEY ("Two paramedic*") OR TITLE-ABS-KEY ("Two person*") OR TITLE-ABS-KEY ("Two provider*") OR TITLE-ABS-KEY ("Two rescuer*") OR TITLE-ABS-KEY ("Two-man crew*") OR TITLE-ABS-KEY (" Two-man team*") OR TITLE-ABS-KEY ("Two-member team*") OR TITLE-ABS-KEY ("Two-person crew*") OR TITLE-ABS-KEY ("Two-person team*") OR TITLE-ABS-KEY ("Two-rescuer team*")) AND PUB YEAR > 2004 AND PUBYEAR < 2024 AND (LIMIT-TO (SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "NURS") OR LIMIT-TO (SUBJAREA , "HEAL"))

4. Cochrane Library

Filter: 2005-2023
Trials only (no reviews and protocols were applicable or aimed to topic)
"Cardiopulmonary Resuscitation" OR "CPR" OR "Resuscitation" OR "Cardiac arrest" OR "Heart arrest" OR "Advanced life support" OR "ALS" OR "Advanced Cardiovascular Life Support" OR "ACLS" OR "Advanced Resuscitation Procedure"
AND
"2 health care professional" OR "2 health care provider" OR "2 paramedic" OR "2 rescuer" OR "Two health care professional" OR "Two paramedic" OR "Two person" OR "Two provider" OR "Two rescuer" OR "Two-man crew" OR " Two-man team" OR "Two-member team" OR "Two-person crew" OR "Two-person team" OR "Two-rescuer team"

5. Clinical trials. gov

Condition or disease
Cardiac arrest
Other
Advanced life support OR Advanced Cardiac Life Support
Intervention
"cardiopulmonary resuscitation \(CPR\)" OR "two provider*"

Search strategy documentation:

Search summary:
November 30th, 2023

Database/platform	Date of search	Number or results
MEDLINE (PubMed)	30/11/2023	127
Web of science	30/11/2023	132
Scopus	30/11/2023	120
Cochrane Library Trials	30/11/2023	97
Clinicatrials.gov	30/11/2023	19

Total records: 495
Total records after deduplication: 216

Reference search	30/11/2023	1

2) PRISMA – Checklist

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	4
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	6
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	7
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	7
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	7
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	8
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	Appendix A
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	8
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	8
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	8
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	9

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	9
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	9
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Appendix B
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	10
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	13
Limitations	20	Discuss the limitations of the scoping review process.	15
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	16
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	17

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.