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HABILITAČNÍ PRÁCE

Anesteziologie, intenzivní medicína a algeziologie

Infekce spojené se zdravotní péčí u onemocnění mozku a páteře

MUDr. Věra Špatenková, Ph.D.

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Poděkování

Ráda bych poděkovala celému lékařskému i nelékařskému týmu naší neurointenzivní jednotky, bez jejichž přispění a pomoci bych nemohla realizovat tento Preventivní multimodální protokol nozokomiálních infekcí. Jmenovitě bych chtěla poděkovat prof. MUDr. P. Suchomelovi Ph.D., přednostovi Neurocentra Krajské nemocnice Liberec za jeho významnou podporu při realizaci projektu, prof. MUDr. RNDr. O. Bradáčovi, Ph.D. z Neurochirurgické kliniky dětí a dospělých 2. lékařské fakulty Univerzity Karlovy za statistické zpracování dat a prof. MUDr. P. Štouračovi, Ph.D., přednostovi Kliniky dětské anesteziologie a resuscitace z Fakultní nemocnice Brno a Lékařské fakulty Masarykovy univerzity za inspiraci a podporu při sestavování habilitační práce.

1. Úvod

Infekce spojené se zdravotní péčí (Healthcare-associated Infections, HAI), někdy v literatuře uváděné jako nozokomiální infekce, jsou infekční komplikace, které vznikají v souvislosti s poskytováním zdravotní péče [1-2] a které i v současné době představují významné riziko nejen pro pacienta, ale i pro celou zdravotní péči [3-5], a proto je velmi důležité věnovat jim pozornost.

Výskyt HAI se liší nejen v jednotlivých zdravotnických zařízeních, ale i na různých pracovištích poskytované zdravotní péče, přičemž jednotky intenzivní péče (JIP) patří mezi nejrizikovější pracoviště [6-7]. I přes neustálou modernizaci technologií a inovace v oblasti farmakologických a nefarmakologických postupů se nedaří četnost HAI zásadním způsobem snižovat ani v dnešní době. Navíc díky novým technologiím je poskytována zdravotní péče stále rizikovějším a křehčím pacientům, kteří by tuto šanci dříve neměli. Paradoxně tak v praxi dochází k tomu, že ačkoliv nové technologie umožňují poskytovat vysoce specializovanou neurointenzivní péči a zlepšovat tak prognózu u neurointenzivních pacientů, častý výskyt HAI prognózu u těchto akutních pacientů zase zhoršuje [8-13]. Navíc na vzniku HAI se podílí řada faktorů, z nichž se mnohé dosud nepodařilo plně identifikovat.

Tímto konstatováním není zamýšleno zpochybňovat výsledky modernizace, ale obrátit pozornost zpět k základním preventivním opatřením a vědomí, že i vývoj nových antibiotik a technologií má své limity. Investice do nastavení programu prevence a kontroly infekcí [2] se tak jeví jako bezpečnější, osvědčená strategie, a to i vzhledem k tomu, že HAI se řadí mezi preventabilní onemocnění [14]. Tato práce si klade za cíl upozornit právě na preventabilitu infekčních komplikací v neurointenzivní

péči a na to, že nastavením hygienických a dalších preventivních opatření, jim lze efektivněji přecházet.

Výskyt HAI lze tedy považovat za indikátor kvality a bezpečnosti zdravotní péče [15]. I na naší neurointenzivní jednotce (NJ) v Krajské nemocnici Liberec patří prevence a kontrola HAI mezi základní strategické cíle. Prevenci a kontrole infekcí se v neurointenzivní péči věnujeme již od roku 2001. V lednu 2001 jsme implementovali Preventivní multimodální protokol nozokomiálních infekcí v neurointenzivní péči, který se skládá za tří částí, z preventivních hygienických a protiepidemických opatření, antibiotické politiky a kontroly infekcí.

Předkládaná habilitační práce dle § 72 odst. 3 písmena b) zákona o vysokých školách je souhrnem čtyř komentovaných prací, kterým předchází teoretický úvod věnující se problematice infekcí spojených se zdravotní péčí, včetně aktuálního přehledu u onemocnění mozku a páteře, a Preventivní multimodální protokol nozokomiálních infekcí na NJ Neurocentra Krajské nemocnice Liberec. Tyto komentované práce sledují efektivitu nastaveného protokolu v prevenci a kontrole infekcí v naší neurointenzivní péči.

1.1. Prevence a kontrola infekcí související se zdravotní péčí

Infekce spojené se zdravotní péčí se stávají nevyhnutelným faktorem, který lze pouze více či méně úspěšně redukovat. Podle zákona č. 372/2011 Sb. o zdravotnických službách a o podmínkách jejich poskytovatelů musí mít provozovatel zdravotnických zařízení implantovaný program prevence a kontroly infekcí [16]. Pro potřeby zavedení a zdokonalování tohoto programu v klinické praxi byl Ministerstvem zdravotnictví České republiky vypracovaný metodický pokyn [2]. Jeho cílem je zvýšit kvalitu a bezpečnost poskytované zdravotní péče prostřednictvím systémových opatření, která vedou ke snížení rizika vzniku a šíření HAI. Tento dokument sestává ze tří oblastí: 1) Zajištění základních hygienických požadavků pro provoz zdravotnického zařízení, 2) Zajištění standardních opatření k eliminaci rizika přenosu infekčních agens při poskytování zdravotní péče, 3) Provádění cílené, klinicky orientované prevence a kontroly infekcí. Pro funkčnost celého programu je nezbytné jeho správné nastavení tak, aby byl důsledně prováděn celým týmem 24 hodin denně a aby byly postupy a protokoly jasně definovány a průběžně vyhodnocovány ve vztahu k riziku vzniku infekcí. Dále je třeba nezanedbávat průběžnou edukaci personálu a podpory poskytovatele zdravotní péče.

K realizaci programu prevence a kontroly infekcí ve zdravotnických zařízeních poskytovatelů akutní lůžkové péče přispívá v České republice také plnění akreditačního standardu Hygieny nemocničního prostředí a protiepidemických opatření od Spojené akreditační komise [15].

Přestože v současné době zaujímá prevence a kontrola infekcí souvisejících se zdravotní péčí významnou úlohu, nepodařilo se jejich výskyt zásadnějším způsobem snížit. Nejedná se pouze o lokální výsledky, infekce spojené se zdravotní péčí jsou

celosvětovým problémem. Podle první velké bodové prevalenční studie HAI pořádané Evropským centrem pro prevenci a kontrolu infekcí (European Centre for Disease Prevention and Control, ECDC), která analyzovala výsledky 231 459 pacientů z 947 nemocnic z evropských zemí za období 2011–2012, se tato prevalence infekcí pohybovala v rozmezí od 2,3 do 10,8 %. Tato studie současně ukázala, že na pracovištích intenzivní péče se HAI vyskytly nejčastěji. Přítomnost jedné infekce byla sledována u 19, 5 % pacientů [3]. V další rozsáhlejší bodové prevalenční studii pořádané ECDC v roce 2016–2017, které se účastnilo 325 737 pacientů z 1274 evropských nemocnic, se prevalence HAI na pracovištích JIP snížila pouze minimálně, a to na 19,1 % [4]. V letech 2022–2023 proběhla třetí bodová prevalenční studie, opět pořádaná ECDC, která ukázala mírný nárůst prevalence HAI na JIP, přítomnost jedné infekce byla zjištěna u 20,5 % pacientů. Studie se účastnilo 309 504 pacientů z 1 332 nemocnic [5].

1.1.1. Hygienická a protiepidemická opatření

Hygienická a protiepidemická opatření tvoří základní předpoklady pro zamezení šíření infekcí [17-23]. Jedná se o komplexní soubor postupů k prevenci infekcí souvisejících s poskytováním léčebné a ošetřovatelské péče, jehož principem je čistota, dezinfekce a zachování sterility. Jednotlivá opatření jsou kategorizována pro vybavení a prostory celého pracoviště, a dále pro pacienta, personál, další osoby přítomné na pracovišti. Zajištění prevence infekcí spočívá nejen v zavedení jednotlivých opatření, ale hlavně v jejich 24hodinovém důsledném dodržování všemi osobami vyskytujícími se na pracovišti. Nedílnou nutností k uskutečnění celého

procesu jsou účinné kontroly s vyhodnocením a hledáním příčin vzniku infekčních komplikací. Kontroly se zaměřují na důvody, proč nebyla dodržena opatření, a vedou k návrhu funkčních proveditelných postupů.

Mezi základní hygienické postupy pro zdravotnický personál patří hygiena rukou, používání rukavic, ochranných brýlí, ústenek a ochranných plášťů, respirační hygiena, prevence poranění jehlou nebo jinými ostrými předměty.

U hygienických postupů týkajících se pacienta je nezbytné respektovat individualizaci všech ošetřovacích a vyšetřovacích pomůcek a postupů. Navíc v neurointenzivní péči je třeba při použití drenáží, katétrů, infuzních systémů, umělé plicní ventilace a dalších systémů, pečlivě zvážit jejich indikaci, a důležité je zbytečně neprodlužovat dobu jejich zavedení. Další doporučení se týkají preferování jednorázových pomůcek, používání uzavřených systémů s minimálním a pouze nutným odpojením, využití systémů s porty, výměny systémů a jejich ošetřování.

Velmi významnou úlohu v zajištění hygieny pacienta představuje pravidelná výměna lůžkovin, izolační režim u každého infekčního pacienta s důrazem na izolaci pacientů s infekcí nebo kolonizací multirezistentními (MDR, multidrug resistant) bakteriemi ESBL (Extended spectrum β-lactamases), MRSA (methicilin-rezistentní *Staphylococcus aureus*), VRE (Vancomycin-resistantní Enterococcus) a CPE (Carbapenemase producing Enterobacteriaceae).

K hygienickým postupům týkajících se celého pracoviště patří čištění a dezinfekce povrchů včetně lůžka a okolí pacienta, manipulace s odpady, pravidelný úklid a malování.

1.1.1.1. Hygiena rukou

Hygiena rukou patří mezi základní účinná opatření v prevenci přenosu infekčního agens a současně je i ekonomicky nejefektivnější [24]. Přestože se jedná o snadno realizovatelné opatření, stále dochází v běžné klinické praxi k nedůslednosti v jeho dodržování, na což chtěla upozornit Světová zdravotnická organizace (World Health Organization, WHO) v rámci svého programu Save lives: Clean your hands (Zachraň životy: Umývej si ruce). Organizace šíří osvětu ve společnosti, připravuje různé typy edukačních materiálů, a také vyhlásila 5. května Světovým dnem hygieny rukou (Word Hand Hygiene Day). Datum bylo zvoleno symbolicky, 5. 5. má připomínat nezbytnost hygieny pěti a pěti prstů na obou rukách [25].

V neurointenzivní péči kontaminované ruce zdravotnického personálu představují velmi vysoké riziko pro přenos infekcí, zejména pokud jsou kontaminovány MDR mikroorganismy. K šíření infekce může dojít nejen při jejich přímém kontaktu s pacienty, ale i nepřímou cestou skrze kontaminované předměty a přístroje. Nebezpečí přenosu prostřednictvím rukou hrozí i dalším osobám dostávajícím se do styku s těmito předměty a přístroji anebo s nemocným. Jedná se především o osoby navštěvující pacienty a další pracovníky vyskytující se na pracovišti neurointenzivní péče.

Funkční nastavení dodržování základních principů hygieny rukou závisí na jednotlivých pracovištích. Za klíčový faktor lze považovat poučenost personálu, který si je vědom toho, jak hygienu rukou provádět (3 ml dezinfekčního roztoku vtírat do suchých rukou po dobu 30 s), kdy ji nezbytně provádět (před a po každém kontaktu s pacientem, i při použití rukavic) a proč je důležité její důsledné dodržování (omezit riziko přenosu infekčního agens). Nezbytným předpokladem v tomto směru je

dostupnost dezinfekčního roztoku u každého intenzivního lůžka, u umyvadla, na místě vyšetřování pacienta, v místnostech čištění a dekontaminace pomůcek, nástrojů atd. Důležitou úlohu hraje i výběr dezinfekčního prostředku, nádoby na dezinfekci, pumpičky nebo použití automatických dávkovačů. Pokud je vyžadováno striktní dodržování pravidel, je podstatné poskytnout za tímto účelem i odpovídající a funkční podmínky.

1.1.1.2. Mikrobiologický screening

Mikrobiologický screening se provádí s cílem získat povědomí o výskytu MDR mikroorganismů u pacienta a prostředí pracoviště [26]. Jedná se o kontrolní systém, který zahrnuje buď pravidelné nebo nepravidelné mikrobiologické stěry, jež slouží u pacienta k adekvátní empirické antibiotické terapii, dále ke znalosti epidemiologické situace na pracovišti, k navýšení hygienických opatření nebo rychlé izolaci pacientů, k efektivnějšímu úklidu prostředí atp.

Mikrobiologické stěry se u pacientů provádějí po celou dobu hospitalizace na neurointenzivní jednotce, přičemž první odběr by měl proběhnout po přijetí [27-30], zejména u pacientů přijímaných z rizikového prostředí, u nichž může být výskyt MDR mikroorganismů vyšší. Mikrobiologické vyšetření se provádí ze sekretu nosu, orofaryngu, tracheálního aspirátu, moči, z perianální oblasti, likvoru, dále z katétru (arteriální, centrální žilní, nitrolební) a drénu (zevní komorová a lumbální drenáž).

Při provádění mikrobiologického odběru je nezbytné dodržovat doporučený postup a zabránit kontaminaci vzorku.

Infekce způsobené MDR bakteriemi patří mezi nejzávažnější, ovšem bez stěrů a pravidelných screeningů nemusí dojít k jejich včasnému odhalení.

1.2. Antibiotická politika

Cílem racionální antibiotické politiky je zachování účinnosti antibiotik. V klinické praxi to znamená, vyhnout se především jejich nadbytečnému používání, aby nedocházelo ke ztrátě jejich efektivity v důsledku rozvoje rezistence. Současná doba sice přináší stále nové typy antibiotik, ale bohužel, jejich vývoj není neomezený. Proto je nastavení systému antibiotické politiky [31-33] důležitým aspektem na všech úrovních poskytované zdravotní péče. V intenzivní péči vyznívá tato otázka ještě naléhavěji, protože JIP patří mezi zdravotnická pracoviště s nejčastějším užíváním antibiotik. Jak ukazuje první bodová prevalenční studie pořádaná ECDC (2011–2012), na JIP bylo antibiotikum podáno u 56,5 % pacientů [3]. Situace se bohužel výrazně nezměnila ani v druhé bodové prevalenční studii (2016–2017), kde antibiotika užívalo 55,6 % pacientů [4], třetí prevalenční studie (2022–2023) pak dokonce ukázala nárůst používání antibiotik na JIP (59,5 % pacientů) [5].

Základem racionální antibiotické politiky je vyvarovat se zbytečnému a neindikovanému nadužíváním antibiotik, a to jak v terapeutické, tak i v profylaktické indikaci [1]. Jedním ze zásadních principů terapeutického podání antibiotika je jeho podání u klinicky manifestované bakteriální infekce, ne u kolonizace. Dalšího snížení spotřeby antibiotik lze dosáhnout včasným zvládnutím infekce u pacienta v intenzivní péči, k čemuž je nezbytná rychlá identifikace bakteriální infekce a následně okamžité podání antibiotika, přičemž je dbáno na průkaznost mikrobiálního původce infekce, na deeskalaci počátečního antibiotika s širším antimikrobiálním spektrem a na podání antibiotika podle farmakokineticko-farmakodynamických principů. Podstatné je i zamezit zbytečnému prodlužování doby podávání antibiotika.

Racionální antibiotická politika má své důležité místo také v profylaktickém používání antibiotik. Mezi hlavní obecné zásady antibiotické profylaxe patří dodržování podávání antibiotika jen u indikovaných případů. V neurochirurgii se jedná především o indikaci prevence infekce v místě chirurgického výkonu (Surgical Site Infection, SSI) po neurochirurgických operacích a v neurotraumatologii prevence neuroinfekce u otevřeného kraniocerebrálního poranění s likvoreou. Dále je nezbytné věnovat pozornost výběru antibiotika a jeho podání v dostatečné dávce. U operací je navíc nutné dodržovat jeho správné načasování před začátkem operace, opakovat dávky v průběhu operace podle délky výkonu nebo velikosti krevních ztrát, a dodržovat správnou délku indikované profylaxe.

K implementaci racionální antibiotické politiky je nezbytný komplexní přístup, který vyžaduje úzkou spolupráci s antibiotickým střediskem a případně s klinickým farmaceutem, jehož zapojení se v poslední době stále častěji uplatňuje. Za účelem nastavení racionální antibiotické politiky na různých pracovištích vznikly programy v rámci mezinárodních organizací WHO a ECDC, v České republice pak v rámci Národního antibiotického programu (NAP) a Akčního plánu NAP.

1.2.1. Antibiotická rezistence

Nárůst antibiotické rezistence je v současné době celosvětovým problémem a věnuje se jí stále větší pozornost. V Evropě se jí zabývá ECDC ve svých již výše zmiňovaných evropských bodových prevalenčních studiích [3-5]. Cílem organizace je získat objektivní data o současné situaci ohledně antibiotické rezistence. Sledování

výskytu MDR bakterií umožňuje nahlížet na problematiku v širším, evropském kontextu a na různých úrovních jednotlivých zdravotnických zařízeních.

Avšak vedle vyhodnocování statistických údajů velkých studií je pro orientaci na vlastním pracovišti intenzivní péče nezbytná znalost lokální epidemiologické situace. Tato data získává pracoviště z mikrobiologických screeningů jednak z prostředí NJ a dále od pacientů, a to již při přijetí.

1.3. Infekce spojené se zdravotní péčí u onemocnění mozku a páteře

Infekce spojené se zdravotní péčí jsou definovány jako infekce vzniklé 48 hodin po kontaktu se zdravotnickou péčí [34]. Infekce související s hospitalizací se rozdělují na infekce vztahující se k současné nebo k předešlé hospitalizaci. Mezi infekce spojené s předchozí hospitalizací se v neurochirurgii nejčastěji řadí SSI.

Mezi rizikové faktory ovlivňující vznik HAI patří délka hospitalizace, chronická interní onemocnění, vyšší Acute Physiology and Chronic Health Evaluation (APACHE) II. score [35], neurointenzivní péče s invazivními vstupy a umělou plicní ventilací, podávání antimikrobiálních léčiv a kolonizace MDR mikroorganismy [33].

Výskyt HAI u pacienta vyžaduje další diagnostické a terapeutické intervence, navýšení spotřeby antibiotik. Navíc dochází i ke změně celé epidemiologické situace na pracovišti, která si žádá zavedení různých opatření proti šíření infekce a MDR mikroorganismů. Prokazatelně se tak zvyšují náklady na léčbu pacienta [36-38] a prodlužuje se doba hospitalizace [39-40].

Pro úspěšné zvládnutí HAI je zásadní její včasné rozpoznání. Diagnostika infekce vychází z klinických symptomů, laboratorních nálezů (hematologické, biochemické, mikrobiologické) a ze zobrazovacích metod. Důležitým a současně obtížným aspektem v diagnostice infekce v neurointenzivní péče je její odlišení od kolonizace. Významnou úlohu zaujímá i rozpoznání kontaminace mikrobiologického vzorku.

Mezi nejfrekventovanější primární onemocnění mozku, kde se vyskytují HAI, patří dle literatury kraniotraumata (41 % pacientů) [41]. Následuje akutní krvácení do mozku (23, 1 % pacientů) [8], a třetí nejčastější diagnózou je akutní ischemická příhoda

(15 % pacientů), jak uvádí Vermeijova multicentrická studie z 11 holandských center [42].

1.3.1. Neuroinfekce

Neuroinfekce související se zdravotní péčí patří mezi nejtěžší infekční komplikace v neurointenzivní péči, z nichž za nejzávažnější lze považovat neuroinfekce vyvolané MDR mikroorganismy.

Neuroinfekce, mezi něž se řadí absces mozku nebo míchy, subdurální nebo epidurální empyém, meningitis a ventriculitis, zvyšují riziko morbidity a mortality u neurointenzivních pacientů. Navíc jejich diagnostika nemusí být vždy zcela jednoduchá. Spočívá v komplexní analýze klinického, laboratorního a zobrazovacího vyšetření.

Klinická diagnostika vychází z nálezu nově vzniklých nebo zhoršujících se neurologických symptomů. Mezi klinické příznaky patří cefalea, vomitus, křeče, meningeální příznaky, kvalitativní nebo kvantitativní porucha vědomí. Ovšem nelze se plně spolehnout na febrilie, protože u neurointenzivního pacienta nemusí vždy souviset s infekční etiologií.

Standardní laboratorní vyšetření se provádí z krve a likvoru. Velký význam zde zaujímá mikrobiologické vyšetření, a to ze všech potenciálních zdrojů infekce. Mikrobiologická diagnostika původce infekce se provádí z likvoru, abscesu, empyému, nitrolebních katetrů a čidel a zahrnuje mikroskopické vyšetření, aerobní a anaerobní kultivace, rychlé molekulární metody.

Zobrazovací metody slouží k diagnostice strukturálních forem infekčních komplikací.

Terapeutický postup spočívá v zajištění vitálních funkcí, včasném podání empirické antibiotické terapie a v následné úpravě antibiotika podle vyvolávajícího infekčního agens. Při výběru antibiotika je třeba vycházet ze znalosti původce infekce a současně dbát na farmakodynamické a farmakokinetické charakteristiky antibiotika, a zvažovat důsledky případného dlouhodobého podávání. Součástí léčebného postupu může být i neurochirurgická intervence. Jejím cílem je pak získání vzorku na mikrobiologické vyšetření a exstirpace infekčního ložiska nebo extrakce shuntu, zevní drenáže nebo nitrolebního čidla.

V neurointenzivní péči se neuroinfekce související se zdravotní péčí vyskytují převážně u neurochirurgických neurointenzivních pacientů. Pokud neuroinfekce vznikají v souvislosti s neurochirurgickým výkonem, jedná se o pooperační neuroinfekce, které se řadí mezi SSI [34]. Tyto infekce lze považovat za nejzávažnější skupinu infekcí orgánů a tělesných prostor. Endovaskulární neurointervence mají na rozdíl od neurochirurgických operací velmi nízké infekční riziko [43]. Další skupinou jsou neuroinfekce vznikající v souvislosti s kraniotraumatem bez operační intervence, mezi jejichž nejvýznamnější rizikové faktory vzniku patří otevřené kraniocerebrální poranění a likvorea.

1.3.2. Infekce v místě chirurgického výkonu

Každá operace představuje riziko SSI, avšak u neurochirurgických a spondylochirurgických operací jsou důsledky infekčních komplikací mnohem závažnější, protože mohou způsobit sekundární poškození centrálního nervového systému (CNS).

Infekce v místě chirurgického výkonu jsou podle Úředního věstníku Evropské unie (Official Journal of the European Union) z roku 2018 [34] definovány do 3 skupin:

Povrchové infekce v místě chirurgického výkonu:

Infekce kůže a podkoží, která vznikne do 30 dnů po operaci.

Hluboké infekce v místě chirurgického výkonu:

Infekce fascie, svalů, která vznikne do 30 dnů po operaci bez implantátů a 90 dní po operaci s implantáty.

Infekce orgánů a tělesných prostor:

Infekce orgánů a tělesných prostor (meningitis, ventriculitis, absces), která vznikne do 30 dnů po operaci bez implantátů a 90 dní po operaci s implantáty.

Operace mozku

Incidence SSI po kraniotomii kolísá v rozmezí od 0,8 do 5,6 % [44-45]. U dekompresivní kraniektomie u kraniotraumatu je popisován vyšší výskyt těchto infekcí. Retrospektivní Wettervikova studie popisuje výskyt u 10 % pacientů [46].

Mezi nejvíce rizikové neurochirurgické operace z pohledu infekčních komplikací patří zavedení likvorového shuntu, zevní likvorové drenáže a nitrolebního čidla [47-51]. Výskyt infekčních komplikací velmi kolísá od 0 do 22 % [33]. Při použití implantátů je vznik infekčních komplikací závislý na operační technice, v případě

zevní likvorové drenáže a nitrolebního čidla také velmi záleží na počtu dní jejich zavedení. U zevní likvorové drenáže v Citeriově multicentrické studii patřilo mezi nejrizikovější faktory zavedení katétru mimo operační sál, nebo také již probíhající extrakraniální infekce [52].

Na vznik infekcí má vliv předoperační stav nemocného [53], dále přidružená interní onemocnění (zejména diabetes mellitus), podávání kortikosteroidů [44,54], stav výživy a imunitního systému. Příčiny infekčních komplikací se mohou nacházet i v samotném operačním výkonu, klíčová je především chirurgická technika, nebo zavedení implantátů a drenáží. Významnou úlohu zaujímá i pooperační období, zejména hojení operační rány. Závažné riziko pro vznik infekce představuje dehiscence operační rány a likvorea [44].

V etiologii SSI u operací mozku převládají grampozitivní stafylokoky (*Staphylococcus aureus,* koaguláza negativní stafylokoky). V poslední době také přibývají práce, které upozorňují na vzestup gramnegativních tyčinek, zejména *Acinetobacter species*. U zevní likvorové drenáže dokonce Citeriova práce uvádí rovnocenný výskyt grampozitivních a gramnegativních bakterií [52].

Terapie SSI spočívá v použití antibiotik, která dostatečně pronikají do CNS. Po úvodní empirické antibiotické terapii s pokrytím grampozitivních a gramnegativních bakterií, zahájené co nejdříve, následuje cílená antibiotická terapie. Doba podávání je nejdelší u abscesu mozku (4-6 týdnů), u katétru pak záleží, jak dlouho je zaveden nebo zda je ponechán, vyměněn nebo extrahován. U těžkých neuroinfekcí je možné podat některá antibiotika (aminoglykosidy a vancomycin) intratekálně a intraventikulárně [55-57]. Určité typy infekčních komplikací, zejména absces mozku, subdurální nebo epidurální empyém, vyžadují další neurochirurgickou intervenci.

Infekce v místě chirurgického výkonu zvyšují ekonomickou náročnost neurochirurgických operací, která souvisí s antibiotickou terapií, reoperací a rehospitalizací. Tyto infekce patří mezi nejčastější příčiny 30-denní neplánované rehospitalizace (analýza databáze ACS, American College of Surgeons, u 40 802 elektivních a akutních operacích mozku, OR 4,90; p<0,001) [58]. Cílem neurochirurgické péče je tedy snaha o co nejnižší výskyt infekcí v místě chirurgického výkonu. K tomu by měla sloužit společně s antibiotickou profylaxí i preventivní hygienická opatření. Řada prací ukazuje, že aktivní přístup k jejich nastavení a dodržování pomocí protokolu kontroly infekcí vede k výraznému snížení neuroinfekcí u neurochirurgických pacientů [59-61].

Operace páteře

Incidence SSI po operacích páteře je v literatuře popisována v poměrně širokém rozmezí od 0,0 do 18 % [62-69]. Mezi nejrizikovější operace se řadí výkony s použitím implantátů (6 -18 %) [70]. Avšak novější, modernější, minimálně invazivní operační techniky, například endoskopické výkony, toto riziko snižují [71]. I přes vývoj technologií ale nelze opomíjet základní faktory, které ovlivňují vznik infekcí po operaci páteře, mezi něž se řadí obezita [72], kouření nebo diabetes mellitus. Ansorgeova práce též upozorňuje na zvýšené riziko infekcí v místě chirurgického výkonu zapříčiněné gramnegativními bakteriemi u perioperačně zavedeného permanentního močového katétru, a to zejména u žen [73]. V pooperačním období mohou nastat infekční komplikace u nehojící se operační rány, zejména při dehiscenci s likvoreou.

Tyto infekce se diagnostikují jednak podle lokální situace v operační ráně jako je erytém, otok, hnisavá sekrece, a pak podle bolesti a přítomnosti febrilií nebo jiných celkových příznaků. Pro potvrzení infekce je zapotřebí laboratorního vyšetření, zaměřujícího se především na parametry zánětu a mikrobiologické nálezy. Významnou úlohu v rámci diagnostických postupů zaujímají zobrazovací metody.

V etiologii infekce SSI u operací páteře převládají grampozitivní stafylokoky, zejména *Staphylococcus aureus.*

Terapie SSI, v úvodu empirická, vyžaduje nasazení širokospektrých antibiotik a následně se cíleně upravuje podle původce infekce. Délka podávání antibiotické terapie se liší podle typu infekce a podle typu chirurgické intervence. Doba nasazení léčiva se prodlužuje při ponechání implantátů, přičemž u hluboké infekce s ponecháním implantátů se intravenózní antibiotika mohou podávat 4 až 6 týdnů. Ještě delší antibiotická terapie, až 3 měsíce podle zánětlivých parametrů, se nasazuje v případě pooperační discitidy nebo osteomyelitity. Avšak názory na takto dlouhou antibiotickou terapii se v odborné literatuře liší, na což poukazuje i Dowdell ve své studii [70].

Nezbytnou součástí léčebného postupu u SSI je chirurgická intervence s odebráním vzorku na mikrobiologické vyšetření a s odstraněním nekrotických a infekcí změněných tkání.

Vznik SSI představuje riziko u každého operačního výkonu, ale u operací páteře je ještě vyšší vzhledem k lokalizaci operované oblasti a možnosti sekundárního poškození míchy a dalších nervových struktur. Proto preventivní opatření a monitorování výskytu těchto komplikací zaujímají tak důležité místo [74-78]. Tím, jak vypadá prevence SSI po operacích páteře v mezinárodním kontextu, se zabýval průzkum specialistů ve spinální chirurgii v období od listopadu 2019 do dubna 2020.

Výsledky dotazníku od 472 chirurgů však odhalily především značnou nejednotnost v zavádění preventivních strategií v před, peri a pooperačním období na jednotlivých pracovištích. Průzkum tak především zvýšil zájem o sjednocení doporučení ohledně prevence infekcí a podnítil snahu vycházet ze studií s jasně definovanou populací pacientů [79].

1.3.3. Respirační infekce

Respirační infekce související se zdravotní péčí patří mezi nejčastěji se vyskytující extracerebrální infekce v neurointenzivní péči. Tyto infekce se podílejí na horším klinickém výsledku u neurointenzivních pacientů [42, 80-81] a současně jsou spojeny s vyšší ekonomickou náročností neurointenzivní péče [82].

Respirační infekce zahrnují pneumonie vzniklé v souvislosti se zdravotní péčí (HAP, Healthcare-associated pneumonia), respirační infekce v souvislosti s intubací a umělou plicní ventilací: ventilátorová pneumonie (VAP, Ventilator-associated pneumonia,) a ventilátorová tracheobronchitis (VAT, Ventilator- associated tracheobronchitis). Tyto infekce vznikají 48 hodin po kontaktu se zdravotní péčí, a dělí se na časné (do 96 hodin) a pozdní (nad 96 hodin).

Výskyt respiračních infekcí se u jednotlivých typů akutních neurologických a neurochirurgických onemocnění liší. Mezi nejrizikovější onemocnění patří akutní poranění mozku. Zygun ve své práci u těžkého kraniotraumatu uvádí výskyt VAP u 45 % pacientů [83]. U akutního mozkového krvácení se pneumonie vyskytují od 17 % [84] do 19, 6 % pacientů % [85]. Méně rizikovou skupinou jsou pacienti s ischemickou

cévní mozkovou příhodou. U těchto pacientů je četnost pneumonií nejnižší, v rozmezí od 5,1 % [86] do 7,1 % pacientů [87].

Diagnostika respirační infekce vychází 1) z klinických symptomů – nově vzniklých febrilií > 38 °C; 2) ze zvýšené respirační sekrece nebo purulentní sekrece; 3) z laboratorních parametrů – vzestupu zánětlivých parametrů, poruchy oxygenace; 4) z mikrobiologického nálezu; 5) ze zobrazovacích metod – nový infiltrát na rtg plic u HAP a VAP.

Antibiotickou terapii je nutné podat co nejdříve, obzvláště u nestabilních pacientů s poruchou oxygenace. Výběr antibiotika ovlivňuje čas vzniku infekce, časné respirační infekce jsou způsobeny převážně grampozitivními bakteriemi narozdíl od pozdních infekcí, které jsou vyvolány především gramnegativní bakteriemi.

Mezi nezávislé prediktory vzniku pneumonie v neurointenzivní péči patří aspirace při poruše vědomí nebo při dysfagii, intubace a tracheostomie [44, 88].

Četnost respiračních HAI se řadí mezi ukazatele kvality péče. Jejich výskyt lze omezit účinnými preventivními opatřeními, jako je v neurointenzivní péči prevence aspirace, ke které u pacienta při vědomí může docházet při dysfagii. Pro prevenci dysfagie u pacientů s cévní mozkovou příhodou vytvořila Cerebrovaskulární sekce České neurologické společnosti standardní protokol – Péče o pacienty s dysfagií po cévní mozkové příhodě [88]. U pacientů s poruchou vědomí lze zamezit aspiraci žaludečního obsahu včasnou intubací. Prevence VAP u invazivního zajištění dýchacích cest se řídí doporučenými postupy [89-90], které spočívají ve snižování mikroaspirace nahromaděného sekretu v subglotickém prostoru pomocí subglotického odsávání a udržování konstantního tlaku v manžetě u tracheální nebo tracheostomické kanyly. Další důležité preventivní zásady se týkají polohy pacienta, péče o hygienu dutiny

ústní, zamezení zbytečného rozpojování dýchacího systému a používání uzavřeného systému pro odsávání sekretu z dýchacích cest.

1.3.4. Infekce krevního řečiště

Infekce krevního řečiště (BSI, blood stream infection) související se zdravotní péčí se řadí mezi méně se vyskytující HAI v neurointenzivní péči [91].

Ke vzniku BSI dochází primárně při kontaminaci cévního katétru (CRBSI, catheter-related blood stream infection), nebo sekundárně při infekci jiného orgánu.

Mezi nejčastější CRBSI patří infekční komplikace spojené s centrálním žilním katétrem (CLABSI, central line-associated blood stream infection). Závažnost CLABSI závisí na etiologickém agens, přičemž nejtěžší infekce bývají obvykle vyvolané MDR mikroorganismy.

Rizikem pro jejich vznik je kontaminace katétru v místě vpichu nebo při rozpojení při aplikaci farmak infuzí. Vzhledem k vysoké preventabilitě těchto infekčních komplikací mají preventivní opatření zásadní význam [92]. Nezbytným předpokladem ke snížení CLABSI je soubor multimodálních preventivních postupů, mezi které patří indikace zavedení centrálního žilního katétru, denní posouzení, zda je katétr stále indikován, přísná aseptická technika zavedení, péče o místo vpichu, nerozpojování infuzních systémů, používání portů, dezinfekce vstupů infuzních systémů a dodržování doporučení pro jejich výměnu.

1.3.5. Infekce močového ústrojí

Infekce močového ústrojí související se zdravotní péčí patří mezi druhé nejčastější extracerebrální infekční komplikace v neurointenzivní péči [33]. Především se jedná o infekce vznikající v souvislosti s permanentním močovým katétrem (CAUTI, catheter-associated urinary tract infection).

Výskyt infekcí močového ústrojí se na jednotlivých neurointenzivních pracovištích liší. Velmi nízké hodnoty uvádí výše zmíněná Vermeijova multicentrická studie z 11 holandských stroke center (4,4 % pacientů) [42] na rozdíl od Wangovy monocentrické retrospektivní studie z neurologické neurointenzivní péče, kde je popisován výskyt močových infekcí násobně vyšší (26, 9 % pacientů) [93].

Rizikem pro vznik močové infekce je bakteriemi kolonizovaný močový katétr. V kultivačním nálezu se vyskytují převážně gramnegativní, často MDR bakterie. Asymptomatické bakteriurie zjištěné při pravidelném mikrobiologickém screeningu je třeba odlišovat od manifestní močové infekce, protože u asymptomatické bakteriurie by se neměla podávat antibiotika z důvodu nárůstu MDR bakterií.

K zajištění nízkého výskytu CAUTI v neurointenzivní péči je potřeba dodržovat preventivní opatření [94-95], zvažovat, zda je indikace zavedení katétru nezbytná a denně ji vyhodnocovat. Permanentní močový katétr je nutné zavádět asepticky, dále se doporučuje používat uzavřené drenážní systémy s porty pro odběr vzorku moči k laboratornímu vyšetření a podle výrobce pak vyměňovat katétry a drenážní systémy.

2. Preventivní multimodální protokol nozokomiálních infekcí na neurointenzivní jednotce Neurocentra v Krajské nemocnici Liberec

Preventivní multimodální protokol nozokomiálních infekcí (dále jen Protokol) jsme do naší neurointenzivní péče implementovali v lednu 2001. V současné době bychom spíše použili označení HAI. Tento novější název totiž lépe vystihuje vztah těchto infekcí v souvislosti s celým rozsahem zdravotní péče, tedy zahrnutím výkonů a ošetření jak v ambulantní péči, tak například při krátkodobé, jednodenní hospitalizaci. Z těchto důvodů je v textu práce místo nozokomiálních infekcí uváděno HAI.

Společně s tímto Protokolem byla v lednu 2001 zavedena Kniha nozokomiálních infekcí a Prospektivní databáze pacientů hospitalizovaných na NJ Neurocentra. Tato databáze pacientů zahrnuje následující parametry:

1) demografické údaje;

2) diagnóza primárního onemocnění;

3) typ přijetí: primární, sekundární do 24 hodin a po 24 hodinách, akutní nebo plánované, rehospitalizace;

4) skórovací systémy: vstupní a celkový TISS (Therapeutic Intervention Scoring System), vstupní GCS (Glasgow Coma Scale), vstupní APACHE II, GOS (Glasgow Outcome Scale) po propuštění z NJ, ASA (American Society of Anesthesiologists);

5) délka hospitalizace na NJ;

6) úmrtnost na NJ;

7) operace: počet, doba, typ operace, reoperace, den hospitalizace, akutní nebo plánovaná, krevní ztráta;

8) drenáže, kanyly, rourky, katétry, umělá plicní ventilace;

9) antibiotika: počet, typ, délka podávání, indikace, empirické nebo cílené podání podle kultivace;

10) mikrobiologická monitorace: MDR bakterie ESBL, MRSA, VRE, CPE;

11) rizikové faktory: podávání kortikosteroidů, transfúze, profylaxe žaludečního nebo duodenálního vředu, diabetes mellitus;

12) infekční komplikace: typ, čas vzniku, rizikové faktory, diagnostika, terapie, HAI je v protokolu je definována podle doporučení jako infekce vzniklá po 48 hodinách po kontaktu se zdravotnickou péčí na základě klinického, laboratorního nálezu včetně nálezů zobrazovacích metod;

infekce v místech chirurgického výkonu je rozdělena na povrchové, hluboké a orgánové infekce;

13) C-reaktivní protein.

Tento Protokol se na naší NJ skládá ze tří základních preventivních postupů: 1) Preventivní hygienická a protiepidemická opatření, 2) Antibiotická politika a 3) Kontrola infekcí.

2.1. Preventivní hygienická a protiepidemická opatření

Základem hygienického a protiepidemického režimu v našem Protokolu je čistota, dezinfekce a zachování sterility. Zásady jsou uvedeny ve standardních pracovních postupech a jsou kategorizovány pro osoby vyskytující se na NJ (personál,

návštěvy a další osoby přítomné na NJ), pacienty a celé pracoviště NJ včetně pomůcek a přístrojů.

Nejdůležitější součásti protokolu:

1) hygiena rukou (dostupnost dezinfekčního prostředku u každého vstupu a u každého lůžka, v místnosti čištění a dekontaminace pomůcek), používání rukavic;

2) bariérová ošetřovací technika: individualizace všech ošetřovacích a vyšetřovacích pomůcek, používání ústenek a ochranných plášťů;

3) oddělení čistých a kontaminovaných postupů;

4) hygiena pacienta 2x denně s výměnou oblečení a ložního prádla;

5) základní principy péče o drenáže, katétry, infuze, odsávání z dýchacích cest, dýchací okruhy: jednorázové pomůcky, uzavřené systémy, minimální nutná doba trvání, minimální a pouze nutné odpojení, používání systémů s porty, pravidelná výměna (periferní žilní katétry, všechny infuzní soupravy, spojovací trubice a porty, permanentní močové katétry) a nepravidelná výměna (centrální žilní katétry, periferní arteriální katétry, tracheální a tracheostomické kanyly);

6) krytí invazivních vstupů a ran: pravidelné výměny, plně zakrývající a neustále suché krytí ran;

7) pravidelný mikrobiologický screening: po přijetí a každý třetí den – nos, krk, trachea, kůže, moč, rektum; denně – likvor, každý vyjmutý katétr mimo periferního žilního katétru;

8) izolace pacientů s MDR bakteriemi ESBL, MRSA, VRE, CPE;

9) vybavení – pravidelný úklid: třikrát denně čištění s dezinfekcí povrchů včetně lůžka, monitorů a dalšího vybavení kolem lůžka, kliky u dveří a podlahy;

10) manipulace s odpady;

11) malování na NJ;

12) vedení dokumentace;

13) pravidelná edukace a důsledná kontrola.

2.2. Antibiotická politika

Základem antibiotické politiky v našem preventivním Protokolu je racionální profylaktické a terapeutické podávání antibiotik. Mezi základní cíle patří:

1) úzká spolupráce s antibiotickým střediskem;

2) eliminace nadužívání antibiotik;

3) profylaktické podání antibiotik:

– operace: podání antibiotika v dostatečné dávce jen před výkonem a během operačního výkonu (dle biologického poločasu antibiotika a krevních ztrát), dodržování načasování před operací, neprodlužování jeho podávání po výkonu,

– zevní komorová a lumbální drenáž: před zavedením s maximálním prodloužením na 48 hodin po zavedení,

– nitrolební čidlo: jen před zavedením,

– likvorea,

– aspirace do plic: do kontrolního RTG vyšetření;

4) terapeutické podání antibiotika: jen při infekci (ne u kolonizace), pokud lze počkat dle klinického průběhu začít terapii až po odebrání vzorku k mikrobiologickému vyšetření, deeskalace podle citlivosti antibiotika;

5) monitorování antibiotik v databázi;

6) monitorování MDR bakterií.

2.3. Kontrola infekcí

Pro evidenci a kontrolu infekcí slouží na NJ Kniha nozokomiálních infekcí a Prospektivní databáze pacientů, které byly zavedeny v lednu 2001 společně s preventivním Protokolem. V Knize nozokomiálních infekcí evidujeme druh a rizikové faktory vzniku HAI s následnou analýzou a návrhem opatření. Prospektivní databáze pacientů je vedena v excelovém souboru, ve kterém se nacházejí údaje vztahující se k infekčním komplikacím u pacientů hospitalizovaných na NJ. Infekce jsou současně hlášeny na oddělení nemocniční hygieny KNL.

3. Komentované práce

Prezentovaná habilitační práce se zabývá problematikou prevence infekčních komplikací v neurointenzivní péči. Ve čtyřech publikacích je vyhodnocen náš přístup v oblasti prevence infekcí spojených se zdravotní péči na naší neurointenzivní jednotce, kde se této problematice věnujeme již dlouhodobě. V roce 2001 byl u nás implementován Preventivní multimodální protokol nozokomiálních infekcí, jehož jsem autorkou. Tento protokol byl na naší neurointenzivní jednotce zaveden o deset let dříve než byl Ministerstvem zdravotnictví České republiky vydán metodický pokyn na podporu zavedení preventivního programu prevence a kontroly infekcí do klinické praxe (2011) [2], přičemž se náš lokální protokol od tohoto metodického pokynu v základních principech neliší.

Účinná realizace komplexního preventivního programu však v roce 2001 nebyla jednoduchá. Úvodní sestavení a zavedení v praxi realizovatelných standardních hygienických a epidemiologických postupů, pravidel pro profylaktické a terapeutické podávání antibiotik a programu kontroly infekcí, zdaleka nepředstavovalo tu nejobtížnější část, ta následovala v samotném každodenním uskutečňování a v udržitelnosti preventivního programu. Zatímco dnes vedení nemocnice vyžaduje dodržování těchto principů na základě nejen metodického pokynu ale i v rámci programu prevence a kontroly infekcí v akreditačním standardu od Spojené akreditační komise [15], v době zavedení našeho protokolu bylo jeho prosazování mnohem složitější. Právě z těchto důvodů jsem zrealizovala první klinické studie, jejichž výsledky měly poukázat na význam preventivního programu. Mým cílem dále bylo získat objektivní data, která by sloužila jako přehled pro naše i jiná oddělení JIP podobně, jako slouží mezinárodní prevalenční velké bodové studie pořádané ECDC [3-

5]. Třetí bodové prevalenční studie v roce 2023 [5] se účastnilo v rámci celé nemocnice i naše oddělení.

Prezentované studie habilitační práce sledují dlouhodobé incidence infekcí spojených se zdravotní péčí, používání antibiotik a výskytu MDR bakterií v prospektivních klinických studiích. Pro zajištění kvality výzkumu jsem zavedla v excelovém souboru Prospektivní databázi pacientů a samostatnou Knihu nozokomiálních infekcí.

Tento výzkum byl rozdělen podle typu studované populace do dvou tematických větších celků. První část se zabývala účinností nastaveného preventivního multimodálního protokolu u pacientů s akutním primárním onemocněním mozku. Výsledky této práce byly publikovány v časopise *BMC Neurology* a publikace má 8 citací dle Web of Science (WoS).

Druhá tematická oblast se vztahuje k primárnímu onemocnění páteře. Tato část výzkumu sledovala výskyt SSI. Vzhledem k různému stupni rizika vzniku SSI u jednotlivých částí páteře [96] byla práce rozdělena na tři prospektivní studie. První výzkumná oblast byla zaměřena na sledování incidence SSI v oblasti hrudní a bederní páteře. Výsledky výzkumu byly publikovány v časopise *Journal of Orthopaedic Surgery and Research* a tato publikace má 9 citací dle WOS. Druhá část výzkumu se týkala incidencí SSI u operací krční páteře z předního a zadního operačního přístupu. Tato práce byla publikována v *The European Journal of Orthopaedic Surgery and Traumatology* a má 3 citace dle WOS, přičemž A. Lerch si vybral naše data do metaanalýzy o drenážích, kterou publikoval v časopise *British Journal of Neurosurgery* [97]. Třetí část výzkumu probíhala u operací krční páteře transorálním přístupem. Tato práce byla publikována v časopise *BMC Anesthesiology*. Celý výzkum o SSI po operacích páteře se stal v roce 2023 pilířem pro obhájení prestižního evropského

certifikátu Centra excelence ve spinální chirurgii od evropské společnosti Spine Society of Europe v oblasti kontroly infekcí.

Ve všech čtyřech prezentovaných publikacích jsem první autorkou.

3.1. Souhrn komentovaných prací vztahujících se k habilitační práci

1. **SPATENKOVA, Vera*(corresponding author)***, Ondrej BRADAC, Daniela FACKOVA, Zdenka BOHUNOVA and Petr SUCHOMEL. Low incidence of multidrug-resistant bacteria and nosocomial infection due to a preventive multimodal nosocomial infection control: a 10-year single centre prospective cohort study in neurocritical care. *Bmc Neurology* [online]. 2018, **18**(23, Article 23). ISSN 1471-2377. Available at: doi:10.1186/s12883-018-1031-6

   Document Type: Article; IF = 2,233; median IF CLINICAL NEUROLOGY – SCIE 2,635; according to AIS CLINICAL NEUROLOGY – SCIE Q2

2. **SPATENKOVA, Vera*(corresponding author)***, Ondrej BRADAC, Zdenek JINDRISEK, Jan HRADIL, Daniela FACKOVA and Milada HALACOVA. Risk factors associated with surgical site infections after thoracic or lumbar surgery: a 6-year single centre prospective cohort study. *Journal Of Orthopaedic Surgery And Research* [online]. 2021, **16**(1, Article 265). ISSN 1749-799X. Available at: doi:10.1186/s13018-021-02418-1

   Document Type: Article; IF = 2,677; median IF ORTHOPEDICS – SCIE 2,620; according to IF ORTHOPEDICS – SCIE (Science Citation Index Expanded) **Q2**

3. **SPATENKOVA, Vera*(corresponding author)***, Ondrej BRADAC, Zuzana MARECKOVA, Petr SUCHOMEL, Jan HRADIL, Eduard KURISCAK and Milada HALACOVA. Incidence of surgical site infections after cervical spine surgery: results of a single-center cohort study adhering to multimodal preventive wound control protocol. *European Journal Of Orthopaedic Surgery*

And Traumatology [online]. 2023, **33**(5), 1997–2004. ISSN 1432-1068. Available at: doi:10.1007/s00590-022-03379-9

Document Type: Article; IF = 1,400; median IF ORTHOPEDICS – ESCI 1,650 + SURGERY – ESCI 1,600; according to IF ORTHOPEDICS – ESCI Q3

4. **SPATENKOVA, Vera*(corresponding author)***, David SILA, Milada HALACOVA, Jan HRADIL, Zdenek KREJZAR and Eduard KURISCAK. Individualized perioperative management in transoral spine surgery: a single-center cohort study evaluating surgical wound complications and wound infections. *Bmc Anesthesiology* [online]. 2022, **22**(1, Article 123). ISSN 1471-2253. Available at: doi:10.1186/s12871-022-01673-x

   Document Type: Article; IF = 2,200; median IF ANESTHESIOLOGY – SCIE 2,900; according to IF ANESTHESIOLOGY – SCIE Q3

3.2. Infekce související se zdravotní péčí u onemocnění mozku

3.2.1. Low incidence of multidrug-resistant bacteria and nosocomial infection due to a preventive multimodal nosocomial infection control: a 10-year single centre prospective cohort study in neurocritical care. BMC Neurology. 2018

První prezentovaná prospektivní klinická studie analyzovala účinnost Preventivního multimodálního protokolu nozokomiálních infekcí na naší NJ již od doby zavedení, tedy od roku 2001. Unikátní byla studie především svým rozsahem, protože konsekutivní sledování trvající více než dvě dekády je ojedinělé i ve světové literatuře. Poskytla tak robustní základ pro další směřování výzkumu. Základní oblast výzkumu byla zaměřena na zásadní postupy snižující výskyt infekčních komplikací v intenzivní péči, na hygienické a protiepidemické postupy, antibiotickou politiku, výskyt MDR bakterií a kontrolu infekcí souvisejících se zdravotní péčí. Cílem práce bylo sledování účinnosti tohoto komplexního preventivního multimodální programu, který do roku 2001 na naší NJ chyběl. Výsledky potvrdily naše očekávání, po zavedení protokolu se incidence infekčních komplikací snížila z 9,1 % pacientů na 4,7 % a byla sledována velmi nízká incidence MDR bakterií (ESBL 1,9 % pacientů a MRSA 1,5 % pacientů). Dále výzkum potvrdil významné prediktory vzniku HAI, tedy zvýšení rizika infekce při zavedení močového katétru, při transfúzi, při výskytu primárně neinfekčních komplikací v operační ráně, a především pak při zajišťování dýchacích cest u umělé plicní ventilace. Díky tomu byla přehodnocena strategie v prevenci infekčních komplikací, došlo k zacílení programu na tyto významné prediktory, k úpravě protokolů a ke změně přístupu k indikacím HAI. Protože neinfekční

komplikace v operační ráně představují závažné riziko vzniku SSI staly se podnětem pro pokračování dalšího výzkumu.

Výsledky této práce také oslovily zahraniční autory k jejímu citování. Čtyři citace souvisejí s důležitostí aktivního preventivního programu. Deng ve své práci z roku 2019 v *Surgical Infections* poukazuje na důležitost aktivního přístupu v prevenci infekcí krevního řečiště [98]. Další dvě citované práce, Onoderova publikace z roku 2021 v *Neurologia medico-chirurgica* [99] a Rafava publikace z roku 2022 v *International Journal of Environmental Research and Public Health* [100], uvádějí naši práci v souvislosti s aktivním přístupem v prevencí HAI u neurointenzivních pacientů. Náš pravidelný mikrobiologický screening prováděný od přijetí a následně každý třetí den zaujal Dantase v jeho práci o prevenci infekcí z roku 2020 v *Rev Rene* [101]. V otázce sledování prognózy, je naše práce citována Lauplandově publikaci z roku 2019 v *Clinical Epidemiology* o řešení prognózy u infekcí krevního řečiště [102].

I když se lékařská věda zabývá prevencí infekčních komplikací mnoho let, tak i přesto je tato otázka v dnešní současné době stále aktuální a žádoucí, zejména v neurointenzivní péči. Naše práce jednoznačně ukazuje, že účinný komplexní multimodálního program má své místo v prevenci a kontrole HAI u neurointenzivních pacientů.

Výsledky této studie byly poprvé prezentovány v roce 2016 formou e-posteru na *Annual Congress European Society of Intensive Care Medicine* v Miláně. Součástí prezentace byl publikovaný abstrakt v *Intensive Care Medicine Experimental,* Spatenkova V, Bradac O, Suchomel. Preventive multimodal nosocomial infection protocol in neurocritical care. 2016;4(S1):426.

Tato výzkumná práce byla publikována v *BMC Neurology*, v dobrém zahraničním recenzovaném časopise s impakt faktorem 2,233, Q2 dle SCIE v kategorii klinické neurologie, open access a časopisem vydávaným v nakladatelství Springer. Tato publikace má 8 citací dle WoS.

ESICM LIVES 2016 <esicm2016@abstractserver.com>

ESICM2016 - Poster Corner Acceptance Notification - A-825-0040-00684

We thank you for submitting the abstract A-825-0040-00684entitled

"PREVENTIVE MULTIMODAL NOSOCOMIAL INFECTION PROTOCOL IN NEUROCRITICAL CARE"

for presentation at our next Annual Congress

We are pleased to inform you that your abstract has been selected as **poster** by the Congress Scientific Committee. Congratulations!

Your abstract above has been assigned the new reference number **0837**.

You will have also to present your poster at the **Poster Corner Session** in the Exhibition Area (Level 0):

Session Title: OUTCOMES IN NEUROINTENSIVE CARE
Session Date: Tuesday, 4 October 2016
Session Time: 16:00 - 17:50
Session Room: Poster Corner

Preventive multimodal nosocomial infection protocol in neurocritical care

SPATENKOVA V [1], BRADAC O [2], SUCHOMEL P [3]

[1] Neurocenter, Neurointensive Care Unit, Regional Hospital, Liberec
[2] Department of Neurosurgery, Central Military Hospital and Charles University, Prague
[3] Neurocenter, Department of Neurosurgery, Regional Hospital, Liberec
CZECH REPUBLIC

29th Annual Congress ESICM, Milan, 1-8 October 2016

Introduction

Nosocomial infections are still an issue in neurocritical care.

AIM OF THE STUDY

Analysis of nosocomial infections in their preventive multimodal protocol in patients with acute brain disease

Methods

- 10-year prospective observational cohort study
- Set in an eight-bed adult neurointensive care unit (NICU)
- 3464 patients with acute brain disease
- Preventive multimodal protocol consists of:
  1) Maintaining a hygienic and epidemiological regime
  2) Correct antibiotic policy
  3) Regular microbiological screening

Methods

Nosocomial infection	N=198 (5.7%) patients
Wound	72 (36.4%)
Respiratory	63 (31.8%)
VAP	34
Urinary	35 (17.7%)
Bloodstream	21 (10.6%)
Others	7 (3.6%)

Results

Parameter	Unit	Total population	NI group	Control group	p value
Number total	pts	3464	198 (5.7%)	3266	
Age	pts		57.2±15.6	56.3±15.6	0.416
Male	pts	2004	117	1887	0.716
BMI			26.8±5.0	26.8±4.9	0.966
NICU stay	day		15.3±11.7	4.8±5.4	<0.001
Total TISS			270632.8 ±231533.1	60415.1 ±92140.3	<0.001
Admission GCS			11.5±3.5	13.1±3.0	<0.001
Admission APACHE II			15.1±5.5	11.8±5.8	<0.001
NICU Mortality	pts	152	21	131	<0.001

Results

Parameter	Unit	Total polulation	NI group	Control group	p value
Artery catheter	pts	907	90	817	<0.001
Radial	pts	873	89	784	0.165
Brachial	pts	14	0	14	0.211
Femoral	pts	36	2	34	0.371
Time NICU	day		8.27±5.45	4.10±3.36	0.094
Central venous catheter	pts	372	64	308	<0.001
Subclavian	pts	336	60	276	0.308
Jugular	pts	19	1	18	0.157
Femoral	pts	16	4	12	0.398
Axillary	pts	7	1	6	0.836
Time in NICU	day		8.20±7.31	4.70±4.92	<0.001
Inserted in NICU	pts	162	41	121	<0.001
Inserted in operating theatre	pts	14	1	13	0.309
Urinary catheter	pts	3166	189	2927	0.008
Epicystostomy	pts	6	1	5	0.247
Time in NICU	day		15.5±11.6	4.7±5.5	<0.001

Results

Parameter	Unit	Total polulation	NI group	Control group	p value
Airways	pts	710	112	598	<0.001
Intubation	pts	327	15	312	<0.001
Tracheostomy	pts	161	29	132	
Both	pts	222	68	154	
Intubation time NICU	day		4.2±2.1	2.9±2.2	<0.001
Tracheostomy time NICU	day		14.2±10.2	8.4±7.8	<0.001
Tracheostomy type					
Percutaneous dilatational	pts	332	87	245	0.456
Classical	pts	43	9	34	
Mechanical ventilation	pts	543	87	456	<0.001
Invasive	pts	539	87	452	<0.001
Time	day		14.1±9.9	5.6±5.9	<0.001
Indication					
Neuro	pts	414	54	360	0.161
Respiratory	pts	32	7	25	

Results

Parameter	Unit	Total polulation	NI group	Control group	p value
ATB profylaxis	pts	2183	127	2056	0.736
Operation	pts	2049	116	1933	0.222
ATB therapy	pts	335	169	166	<0.001
Multiresistant B.					
ESBL	pts	67	6	61	0.566
MRSA	pts	52	7	45	0.320

Multivariate analysis				
NI predictors	Odds Ratio	Lower CL 95%	Upper CL 95%	p value
Artery catheter	3.68	2.65	5.11	< 0.001
Central venous catherer	4.97	3.49	7.07	< 0.001
Airways	7.40	5.27	10.39	< 0.001
Mechanical ventilation	6.74	4.84	9.40	< 0.001
Urine catheter	4.23	1.56	11.50	0.005
Operations	1.65	1.14	2.39	0.008
Drainage	2.42	1.71	3.42	< 0.001
Wound complications	7.21	4.60	11.30	< 0.001
MRSA	2.90	1.22	6.89	0.016

Conclusion

- Nosocomial infections were associated with worse outcome , higher cost.

- Catheter accesses are still risk factors in a preventive multimodal protocol.

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BMC Neurology

RESEARCH ARTICLE Open Access

Low incidence of multidrug-resistant bacteria and nosocomial infection due to a preventive multimodal nosocomial infection control: a 10-year single centre prospective cohort study in neurocritical care

Vera Spatenkova[1*], Ondrej Bradac[2], Daniela Fackova[3], Zdenka Bohunova[3] and Petr Suchomel[4]

Abstract

Background: Nosocomial infection (NI) control is an important issue in neurocritical care due to secondary brain damage and the increased morbidity and mortality of primary acute neurocritical care patients. The primary aim of this study was to determine incidence of nosocomial infections and multidrug-resistant bacteria and seek predictors of nosocomial infections in a preventive multimodal nosocomial infection protocol in the neurointensive care unit (NICU). The secondary aim focused on their impact on stay, mortality and cost in the NICU.

Methods: A10-year, single-centre prospective observational cohort study was conducted on 3464 acute brain disease patients. There were 198 (5.7%) patients with nosocomial infection (wound 2.1%, respiratory 1.8%, urinary 1. 0%, bloodstream 0.7% and other 0.1%); 67 (1.9%) with Extended spectrum beta-lactamase (ESBL); 52 (1.5%) with Methicillin-resistant Staphylococcus aureus (MRSA), nobody with Vancomycin-resistant enterococcus (VRE). The protocol included hygienic, epidemiological status and antibiotic policy. Univariate and multivarite logistic regression analysis was used for identifying predictors of nosocomial infection.

Results: From 198 NI patients, 153 had onset of NI during their NICU stay (4.4%; wound 1.0%, respiratory 1.7%, urinary 0. 9%, bloodstream 0.6%, other 0.1%); ESBL in 31 (0.9%) patients, MRSA in 30 (0.9%) patients. Antibiotics in prophylaxis was given to 63.0% patients (59.2 % for operations), in therapy to 9.7% patients. Predictors of NI in multivariate logistic regression analysis were airways (OR 2.69, 95% CI 1.81-3.99, $p<0.001$), urine catheters (OR 2.77, 95% CI 1.00-7.70, $p=0.050$), NICU stay (OR 1.14, 95% CI 1.12-1.16, $p<0.001$), transfusions (OR 1.79, 95% CI 1.07-2.97, $p=0.025$) antibiotic prophylaxis (OR 0.50, 95% CI 0.34-0.74, $p<0.001$), wound complications (OR 2.30, 95% CI 1.33-3.97, $p=0.003$). NI patients had longer stay ($p<0.001$), higher mortality ($p<0.001$) and higher TISS sums ($p<0.001$) in the NICU.

Conclusions: The presented preventive multimodal nosocomial infection control management was efficient; it gave low rates of nosocomial infections (4.2%) and multidrug-resistant bacteria (ESBL 0.9%, MRSA 0.9% and no VRE). Strong predictors for onset of nosocomial infection were accesses such as airways and urine catheters, NICU stay, antibiotic prophylaxis, wound complications and transfusion. This study confirmed nosocomial infection is associated with worse outcome, higher cost and longer NICU stay.

Keywords: Neurocritical care, Nosocomial infections, Multidrug-resistant bacteria, Outcome, Preventive protocol

* Correspondence: vera.spatenkova@nemlib.cz
[1]Neurocenter, Neurointensive Care Unit, Regional Hospital, Husova 357/10, Regional Hospital, 46063 Liberec, Czech Republic
Full list of author information is available at the end of the article

Background

Nosocomial infections (NI) are still an important issue in neurocritical care due to secondary brain damage and the increased morbidity and mortality of primary acute neurocritical care patients [1–5]. NI is associated with higher antibiotic consumption, thereby worsening the epidemiological situation in the intensive care unit by increasing the occurrence of multidrug-resistant bacteria [6]. For these reasons, they have a significant economic impact because they prolong stay [7–10] in the neurointensive care unit (NICU) and the higher frequency of diagnostic and therapeutic processing significantly raises healthcare costs.

Nosocomial infections can be caused by many risk factors, not all of which have been fully investigated. However, keeping a hygienic and epidemiological regime of critical care [11–13] and the rational use of antibiotics makes a significant impact [14, 15].

The primary aim of this study was to determine incidence of nosocomial infections and multidrug-resistant bacteria and seek predictors of nosocomial infections in a preventive multimodal nosocomial infection protocol in our neurocritical care. The secondary aim focused on their impact on stay, mortality and cost in the NICU.

Method

Study design and setting

A monocentric 10-year observation prospective cohort study was conducted in the entire population of 3464 patients with acute brain disease, admitted to an eight-bed, adult neurological and neurosurgical intensive care unit in the Neurocenter of the 900-bed Regional Hospital with a catchment area of approximately half a million people. The study was performed in the NICU, which consists of four different rooms: one room with one bed, two rooms with two beds and one room with three beds. The study was approved by the Liberec hospital Ethics Committees for Multicentric Clinical Trials.

We prospectively examined the following determined demographic and clinical parameters in our local NICU: brain diagnosis, type of admission (primary, secondary to 24 hours and after 24 hours; acute or planned; rehospitalisation), admission and overall Therapeutic Intervention Scoring System (TISS), admission Glasgow Coma Scale (GCS), admission Acute Physiology and Chronic Health Evaluation (APACHE) II score, length of stay in the NICU, mortality in the NICU, Glasgow Outcome Scale (GOS) upon discharge from the NICU, C-reactive protein (CRP), operations (amount, day of hospital and NICU hospitalisation, acute or planned, reoperation, time and type of operation), American Society of Anesthesiologists (ASA) Score, drainage, airways, mechanical ventilation, catheters (artery, central venous, urine) and tubes, administration of corticoids, transfusions, ulcer prophylaxis and diabetes mellitus.

Preventive multimodal nosocomial infection protocol

In the preventive multimodal nosocomial infection protocol, we categorised hygienic and epidemiological status and antibiotic policy.

Hygienic and epidemiological regime

The basis of the hygienic and epidemiological regime in our preventive multimodal protocol consisted of cleanliness, disinfection, sterilisation, barrier patient care techniques, the separation of clean and contaminated procedures and the regular monthly exchange of disinfectants. We categorised principles for staff, patients and facilities.

1/Staff and visitors

The foremost part of this protocol was maintaining the hygiene and disinfection of all staff members' hands before and after care for each patient, enabled by the bottled disinfectant provided at each entrance and each bed. This rule was also required for visitors. Staff members were not allowed to wear jewellery or watches on their hands and had to keep their fingernails cut short. Internal staff had to wear new, clean, special NICU clothing every day, a protective coat when outside the NICU, and masks, surgical caps and gowns when caring for isolated patients or during invasive medical procedures. Aprons were worn while washing patients. External staff as well as visitors wore surgical gowns, but not overshoes, and only 2 family members were allowed in the patient's room at a time.

2/Patients

Care of the patient was performed on the principle of barrier care techniques. Tools for individual patients including disinfection, stethoscopes, thermometers and washing aids were available by each bed. Patients were washed twice a day with liquid soap. Disinfection soap was used only before entering the operating theatre. Oral hygiene included cleaning teeth with our special toothbrushes with chlorhexidine and subglottic secretion drainage, after washing, the patient's body was rubbed with a non-allergic cream. Patients' clothes and bedding were changed twice a day. Dirty laundry was put in special sacks rather than dropped freely on the floor.

Basic principles of care for drainage, catheters, infusion, suction from the airway, breathing circuit sets, tubes included: 1/single-use products, 2/closed systems, 3/ the minimum necessary duration, 4/minimal and only necessary disconnection, using the port system, 5/the regular (peripheral venous catheters, all infusion sets, connecting tubes and ports) and irregular (central venous catheters, endotracheal tubes and tracheostomy) exchange of all these tubes and catheters was made according to the exchange protocol. Invasive procedures included the sterile insertion of systems and regularly exchanged, fully covering and

Table 1 Demographic and clinical data of population of patients with acute brain disease, with or without nosocomial infection

Parameter	Unit	Total population	NI group	Control group	*p* value
Number total	pts	3464 (100%)	198 (5.7%)	3266 (94.3%)	
January	pts	327 (9.4%)	7 (3.6%)	310 (9.5%)	
February	pts	249 (7.2%)	19 (9.6%)	230 (7.0%)	
March	pts	267 (7.7%)	19 (9.6%)	248 (7.6%)	
April	pts	305 (8.8%)	13 (6.6%)	292 (8.9%)	
May	pts	269 (7.8%)	21 (10.6%)	248 (7.6%)	
June	pts	290 (8.4%)	17 (8.6%)	273 (8.4%)	0.660
July	pts	310 (8.9%)	19 (9.6%)	291 (8.9%)	
August	pts	274 (7.98%)	12 (6.1%)	262 (8.0%)	
September	pts	307 (8.9%)	14 (7.1%)	293 (9.0%)	
October	pts	280 (8.1%)	13 (6.6%)	267 (8.2%)	
November	pts	291 (8.4%)	17 (8.6%)	274 (8.4%)	
December	pts	295 (8.5%)	17 (8.6%)	278 (8.5%)	
Age	pts		57.2±15.6	56.3±15.6	0.416
Male	pts	2004 (57.9%)	117 (59.1%)	1887 (57.8%)	0.716
Weight	kg		78.7±17.1	77.6±15.8	0.423
BMI			26.8±5.0	26.8±4.9	0.966
NICU stay	day		15.3±11.7	4.8±5.4	<0.001
Admission					
Primary	pts	746 (21.5%)	47 (23.7%)	699 (21.4%)	
Secondary to 24 h	pts	739 (21.3%)	51 (25.8%)	688 (21.1%)	0.134
Secondary after 24 h	pts	1979 (57.1%)	100 (50.5%)	1879 (57.5%)	
Acute admission	pts	1020 (29.4%)	70 (35.4%)	950 (29.1%)	<0.001
Rehospitalisation	pts	40 (1.22%)	4 (2.0%)	44 (1.3%)	0.331
Diagnoses					
Stroke	pts	1498 (43.2%)	110 (55.6%)	1388 (42.5%)	
Trauma	pts	472 (13.6%)	27 (13.6%)	445 (13.6%)	
Tumour	pts	1078 (31.1%)	33 (16.7%)	1045 (32.0%)	<0.001
Epilepsy	pts	133 (3.8%)	3 (1.5%)	130 (4.0%)	
Hydrocephalus	pts	119 (3.4%)	13 (6.6%)	106 (3.2%)	
Infection	pts	88 (2.5%)	11 (5.6%)	77 (2.4%)	
Others	pts	75 (2.2%)	1 (0.5%)	74 (2.3%)	
Stroke	pts				<0.001
Ischemic	pts	580 (16.7%)	21 (10.6%)	559 (17.1%)	
ICH	pts	471 (13.6%)	49 (24.7%)	422 (12.9%)	
SAH	pts	447 (12.9%)	40 (20.2%)	407 (12.5%)	
TISS on admission			54.7±1.9	56.0±1.7	<0.001
TISS total			270632.8±231533.1	60415.1±92140..3	<0.001
GCS on admission			11.5±3.5	13.1±3.0	<0.001
APACHE II on admission			15.1±5.5	11.8±5.8	<0.001
GOS on NICU discharge			3.1±1.1	3.9±1.1	<0.001
Mortality in NICU	pts	152 (4.4%)	21 (10.6%)	131 (4.0%)	<0.001
Mortality in NICU	day		16.2±10.4	7.5±5.7	<0.001

Table 1 Demographic and clinical data of population of patients with acute brain disease, with or without nosocomial infection *(Continued)*

Parameter	Unit	Total population	NI group	Control group	*p* value
CRP on admission			31.7±45.6	17.5±39.1	<0.001
CRP postoperative			30.0±44.4	14.0±33.0	<0.001
CRP 1 day after operation			59.8±56.9	31.6±39.6	<0.001
CRP highest in NICU stay			228.0±122.5	66.1±80.3	<0.001

BMI body mass index, *NICU* neurointensive care unit, *ICH* intracerebral haemorrhage, *SAH* subarachnoid haemorrhage, *TISS* Therapeutic Intervention Scoring System, *GCS* Glasgow Coma Scale, *APACHE* Acute Physiology and Chronic Health Evaluation, *GOS* Glasgow Outcome Scale, *CRP* C-reactive protein

constantly dry sterile wound covers. Furthermore, the protocol included the hourly monitoring of residual gastric volume.

The protocol included the regular microbiological screening of nose, throat, trachea, skin, urine and rectum from admission and then every three days, as well as every catheter except the peripheral venous for the timely detection of multidrug-resistant bacteria extended spectrum beta-lactamases (ESBL) or methicillin-resistant Staphylococcus aureus (MRSA) or Vancomycin-resistant enterococcus (VRE).

Patients with an infection or with multidrug-resistant bacteria ESBL and MRSA were completely isolated.

3/Facilities

Daily cleaning with disinfection of surfaces including the bed, monitors, and other equipment around the bed, door handles and floors was conducted three times a day. Walls were cleaned once a day for the isolated patients, otherwise once a week. Each room had its own bucket for surfaces and walls. The floors were mopped using a system of two buckets and a cloth, with each room having its own. All cupboards containing materials and medical equipment were cleaned with disinfectant once a week. Waste was sorted and disposed of using specially marked plastic containers and sacks. After the patient was discharged, the bed was completely disinfected. The room was painted with a washable coating once a year.

Antibiotic policy

The protocol included the monitoring of antibiotics in a local computer database. Antibiotic policy was implemented in close cooperation with the antibiotic centre and intended to keep the rational antibiotic policy aim of eliminating the overuse of antibiotics, especially those not used during bacterial pathogeny colonisation. The indications for using prophylactic antibiotics were surgical procedures (operation, external ventricular and lumbar drainage, intracranial sensors), liquorrhoea and aspiration. The protocol required maintaining dose and timing before the operation, perioperative administration for lengthy operations, and the non-prolongation of antibiotic administration after the operation or drainage or implantation of sensors. Empiric antibiotic therapy was to start after samples were taken for microbiological examination to enable their administration according to culture and sensitivity.

Nosocomial infection

Infections were identified according to clinical symptoms such as fever, bacterial pathogens from secretions, liquor, urine, wounds, catheters, haemoculture with a defined microbiology colony count, imaging methods, biochemical and haematological laboratory tests. Nosocomial infections were defined as infections starting after two calendar days in the hospital. We identified nosocomial infections in 198 patients (5.7%). There were more wound infections (2.1%), than respiratory (1.8%), urinary (1.0%), bloodstream (0.7%) and others (0.1%).

Statistical analysis

Parametric *t*-tests or non-parametric Mann-Whitney U tests were used for comparison of continuous variables. Comparison of categorical parameters was carried out using Chi-square or Fisher tests as appropriate. Univariate logistic regression was used for identifying prognostic factors of NI. Factors from univarite analysis with level of significance defined as $p < 0.1$ were used for multivarite regression analysis, factors with p value <0.1 were left in the model. *P*–values of less than 0.05 were considered significant. STATISTICA 13.2 (TIBCO Software Inc., Palo Alto, CA, USA) software was used for statistical analyses. The control group was defined as patients without nosocomial infections.

Results

We did not find any demographic differences such as age, gender, weight or body mass index between the NI group and the control group, as can be seen in Table 1. However, there was a difference in diagnosis, more patients with stroke and hydrocephalus had more NI than those with other diagnoses. According to the scoring system, patients with nosocomial infection upon admission had significantly lower GCS scale and higher APACHE II. Prognostic parameters were also significantly higher in the NI patients group. They stayed in the NICU longer, had higher mortality and worse Glasgow Coma Scale upon discharge.

Table 2 Characteristics of brain operations

Operation	Unit	Total population *N*=2231	NI group *N*=151	Control group *N*=2080	*p* value
Operation	pts	2231(64.4%)	151(76.3%)	2080 (63.7%)	<0.001
More than 1 operation	pts	214(9.6%)	42(27.8%)	172(8.3%)	<0.001
ASA score			3.8±1.0	3.1±1.1	<0.001
Day of hospitalisation	day		5.5±9.8	7.1±17.1	0.430
Day of NICU			1.6±1.3	1.3±1.1	0.535
Acute operation	pts	905(40.6%)	106(70.2%)	799(38.4%)	<0.001
Reoperation	pts	479(21.5%)	58(38.4%)	421(20.2%)	<0.001
Time of operation	minutes		151.9±108.4	137.7±89.4	0.080
Craniotomy	pts	1361(61.0%)	82(54.3%)	1279(61.5%)	0.080
Craniectomy	pts	363(16.3%)	50(33.1%)	313(15.0%)	<0.001
Trepanation	pts	227(10.2%)	23(15.2%)	204(9.8%)	0.033
Hypophysis	pts	85(3.8%)	0(0.0%)	85(4.1%)	0.011
Shunt	pts	108(4.8%)	12(7.9%)	96(4.6%)	0.066
Others	pts	99(4.4%)	9(6.0%)	90(4.3%)	0.347
Drainage	pts	1678(75.2%)	131(86.8%)	1547(74.4%)	<0.001
Redon	pts	858(38.5%)	49(32.5%)	809(38.9%)	0.001
Time overall	day		2.0±0.9	1.8±1.3	0.395
Gravity drainage	pts	807(36.2%)	75(49.7%)	732(35.2%)	0.029
Time overall	day		3.5±2.1	2.7±2.2	0.004
Lumbar	pts	218(9.8%)	36(23.8%)	182(8.8%)	<0.001
Day overall	day		7.7±5.5	5.1±3.2	<0.001
Ventricular	pts	138(6.2%)	21(13.9%)	117(5.6%)	<0.001
Day overall	day		13.4±9.9	5.9±4.3	<0.001

ASA American Society of Anesthesiologists, *NICU* neurointensive care unit

Table 3 Characteristics of respiratory procedures

Parameter	Unit	Total population *N*=3646	NI group *N*=198	Control group *N*=3266	*p* value
Airways	pts	710 (20.5%)	112 (56.6%)	598 (18.3%)	<0.001
ETT	pts	327(46.1%)	15(13.4%)	312(52.2%)	
TSK	pts	161(22.7%)	29(25.9%)	132(22.1%)	<0.001
ETT/TST	pts	222(31.3%)	68(60.7%)	154(25.8%)	
ETK time NICU	day		4.2±2.1	2.9±2.2	<0.001
ETK time	day		4.4±2.1	2.9±2.3	<0.001
TSK time NICU	day		14.2±10.2	8.4±7.8	<0.001
TSK time	day		21.8±34.6	21.6±62.2	0.980
TSK type Classic	pts	43(11.2%)	9(9.3%)	34(11.9%)	0.456
TSK NICU made	pts	250(65.3%)	75(77.3%)	175(61.2%)	0.006
Mechanical ventilation	pts	543(15.7%)	87(43.9%)	456(14.0%)	<0.001
Invasive	pts	539(99.3%)	87(100.0%)	452(99.1%)	<0.001
Time	day		14.1±9.9	5.6±5.9	<0.001
Indication					
Neuro	pts	414(76.2%)	54(62.1%)	360(78.9%)	0.161
Respiratory	pts	32(5.9%)	7(8.0%)	25(5.5%)	

ETT endotracheal tube, *TST* tracheostomy tube, *NICU* neurointensive care unit

They were also more expensive economically, and had significantly higher total TISS.

Characteristics of brain operations can be seen in Table 2. Patients who had undergone operations and drainage had significantly higher nosocomial infection. These patients had more endotracheal tubes and tracheostomies, mechanical ventilations (Table 3), artery and central venous catheters (Table 4), urine and gastrointestinal tubes (Table 5).

We confirmed transfusions ($p<0.001$), ulcer prophylaxis ($p<0.001$) and corticoids ($p=0.002$) as further parameters influencing nosocomial infection, but we did not see more

Table 4 Characteristics of vascular catheters

Parameter	Unit	Total population *N*=3464	NI group *N*=198	Control group *N*=3266	*p* value
Artery catheter	pts	907(26.2%)	90(45.5%)	817(25.0%)	<0.001
Time	day		9.5±6.6	7.5±3.7	0.018
Number of artery catheters		923(100.0%)	91(100.0%)	832(100.0%)	
Radialis	pts	873(94.6%)	89(97.8%)	784(94.2%)	0.165
Brachialis	pts	14(1.5%)	0(0.0%)	14(1.7%)	0.211
Femoralis	pts	36(3.9%)	2(2.2%)	34(4.1%)	0.371
Left	pts	598(64.8%)	64(70.3%)	534(64.2%)	0.275
Time in NICU	day		8.27±5.45	4.10±3.36	0.094
Time all	day		8.41±5.40	4.41±3.43	0.377
Made in NICU	pts	216(23.4%)	47(51.6%)	169(20.3%)	<0.001
Made in operation theatre	pts	607(65.8%)	46(50.5%)	561(67.4%)	0.001
Cultivation of catheter	pts	691(74.9%)	74(81.3%)	617(74.2%)	0.157
Positive	pts	113(16.4%)	18(24.3%)	95(15.4%)	0.050
STSP	pts	100(88.5%)	13(72.2%)	87(91.6%)	0.018
Haemoculture cultivation	pts	164(17.8%)	31(34.1%)	133(16.0%)	<0.001
Positive	pts	34(20.7%)	9(29.0%)	25(18.8%)	0.206
STSP	pts	18(52.9%)	3(33.3%)	15(60.0%)	0.169
Central venous catheter	pts	372(10.7%)	64(32.3%)	308(9.4%)	<0.001
Time overall	day		9.9±7.4	7.5±3.7	0.077
Number of venous catheter		378(100%)	66(100%)	312(100%)	
Subclavia	pts	336(88.9%)	60(90.9%)	276(88.5%)	0.308
Jugularis	pts	19(5.0%)	1(1.5%)	18(5.8%)	0.157
Femoralis	pts	16(4.2%)	4(6.1%)	12(3.8%)	0.398
Axilaris	pts	7(1.9%)	1(1.5%)	6(1.9%)	0.836
Right	pts	323(85.4%)	59(89.4%)	264(84.6%)	0.164
Type one-line	pts	75(19.8%)	10(15.2%)	65(20.8%)	
Type two-line	pts	192(50.8%)	39(59.1%)	153(49.0%)	0.214
Type three-line	pts	64(16.9%)	8(12.1%)	56(17.9%)	
Time in NICU	day		8.20±7.31	4.70±4.92	<0.001
Time all	day		11.19±8.70	7.24±5.50	<0.001
Made in NICU	pts	162(42.9%)	41(62.1%)	121(38.8%)	<0.001
Made in operation theatre	pts	14(3.7%)	1(1.5%)	13(4.2%)	0.309
Cultivation of catheter	pts	261(69.0%)	45(68.2%)	216(69.2%)	0.977
Positive	pts	52(19.9%)	16(35.6%)	36(16.7%)	0.004
STSP	pts	40(76.9%)	10(62.5%)	30(83.3%)	0.010
Haemoculture cultivation	pts	72(19.0%)	16(24.2%)	56(17.9%)	0.090
Positive	pts	15(20.8%)	2(12.5%)	13(23.2%)	0.352
STSP	pts	13(86.7%)	2(100.0%)	11(84.6%)	0.551

NICU neurointensive care unit, *STSP* Staphylococcus species

Table 5 Characteristics of urine and gastrointestinal procedures

Parameter	Unit	Total population *N*=3464	NI group *N*=198	Control group *N*=3266	*p* value
Urine catheter	pts	3166(91.4%)	189(95.5%)	2927(89.6%)	0.008
Epicystostomy	pts	6(0.2%)	1(0.5%)	5(0.2%)	0.247
Time	day		15.5±11.6	4.7±5.5	<0.001
Time overall	day		22.6±13.1	12.8±9.7	<0.001
Gastrointestinal tube	pts	904(26.1%)	128(64.6%)	776(23.8%)	<0.001
Nasogastric tube	pts	882(25.5%)	125(63.1%)	757(23.2%)	<0.001
Time	day		15.4±11.2	6.2±6.9	<0.001
Time overall	day		19.6±12.6	10.7±9.4	<0.001

nosocomial infection in patients with diabetes mellitus (p=0.203), (Table 6).

ESBL occurred in 1.9% and MRSA in 1.5% of the total population, without differences between NI group patients and the control group (Table 7). We did not have any case of vancomycin-resistant enterococcus.

Antibiotics policy is shown in Table 8. Antibiotic prophylaxis was given to 63% of the total population, mostly (59.2%) in association with operations. In 33.4% of the patients it was only administered in the operating theatre. Prolonged administration in the NICU was associated with more NIs (p=0.017). Antibiotic therapy was given to 9.7% of the total population.

We compared patients with NI onset in the NICU (77.3%) with NI present on admission (22.7%), (Table 9). We identified 153 (4.4%; wound 1.0%, respiratory 1.7%, urinary 0.9%, bloodstream 0.6% and other 0.1%) patients with NI onset in the NICU. Patients with NI onset in the NICU stayed in the NICU significantly longer, and were more expensive, but these patients did not have higher mortality. Multivariate logistic regression analysis seeking significant predictors for onset of NI in the NICU can be seen in Table 10. Our results showed that strong predictors on onset of NI in our neurocritical care were accesses such as airways and urine catheters, NICU stay, antibiotic prophylaxis, wound complications and transfusion. This analysis did not find the multidrug-resistant bacteria as ESBL and MRSA to be a predictor of NI.

Discussion

Maintaining nosocomial infection control management is one marker of quality in neurocritical care. Its target is to improve clinical outcomes and decrease costs in the neurocritical care unit. Preventions of nosocomial infections are an important issue in all medical or surgical critical care units, but in neurocritical care they have

Table 6 Further monitored parameters influencing onset of nosocomial infection

Parameter	Unit	Total population *N*=3464	NI group *N*=198	Control group *N*=3266	*p* value
Corticoids	pts	1172(33.8%)	47(23.7%)	1125(34.4%)	0.002
Dexamethasone	pts	944(27.3%)	31(15.7%)	913(28.0)	<0.001
Methylprednisolone	pts	35(1.0%)	5(2.5%)	30(0.9%)	0.028
Hydrocortisone	pts	241(7.0%)	12(6.1%)	229(7.0%)	0.610
Time	day		6.37±8.78	3.58±2.56	<0.001
Transfusions	pts	176(5.1%)	41(20.7%)	135(4.1%)	<0.001
Number			2.46±8.78	2.57±2.56	0.695
Blood loss	ml		523.77±668.07	380.74±478.76	0.019
Haemoglobin			93.35±21.03	115.34±21.62	<0.001
Ulcer prophylaxis	pts	1838(53.1%)	134(67.7%)	1704(52.2%)	<0.001
One medicine	pts	1669(48.2%)	119(60.1%)	1550(47.5%)	0.406
Sucralfate	pts	758(21.9%)	26(13.1%)	732(22.4%)	0.002
H2 antagonist	pts	196(5.7%)	27(13.6%)	169(5.2%)	<0.001
Omeprazole	pts	1062(30.7%)	97(49.0%)	965(29.5%)	<0.001
Diabetes Mellitus	pts	491(14.2%)	22(11.1%)	469(14.4%)	0.203
Op. wound complication	pts	133(3.8%)	35(17.7%)	98(3.0%)	<0.001
Liquorrhoea	pts	81(2.3%)	23(11.6%)	58(1.8%)	<0.001

Table 7 Multidrug-resistant bacteria ESBL and MRSA in NICU

Parameter	Unit	Total population *N*=3464	NI group *N*=198	Control group *N*=3266	*p* value
Multidrug-resistant	pts	116(3.3%)	12(6.1%)	104(3.2%)	0.029
ESBL	pts	67(1.9%)	6(3.0%)	61(1.9%)	0.566
On admission	pts	36(1.0%)	4(2.0%)	32(1.0%)	0.249
Nose	pts	11(0.3%)	1(0.5%)	10(0.3%)	0.986
Throat	pts	21(0.6%)	4(2.0%)	17(0.5%)	0.051
Trachea	pts	15(0.4%)	1(0.5%)	14(0.4%)	0.725
Urine	pts	19(0.5%)	0(0.0%)	19(0.6%)	0.106
Rectum	pts	31(0.9%)	3(1.5%)	28(0.9%)	0.848
Brain	pts	2(0.1%)	1(0.5%)	1(0.0%)	0.039
Others	pts	5(0.1%)	1(0.5%)	4(0.1%)	0.369
MRSA	pts	52(1.5%)	7(3.5%)	45(1.4%)	0.320
On admission	pts	22(0.6%)	0(0.0%)	22(0.7%)	0.015
Nose	pts	27(0.8%)	4(2.0%)	23(0.7%)	0.766
Throat	pts	11(0.3%)	1(0.5%)	10(0.3%)	0.632
Trachea	pts	14(0.4%)	2(1.0%)	12(0.4%)	0.916
Brain	pts	5(0.1%)	1(0.5%)	4(0.1%)	0.652
Haemoculture	pts	1(0.0%)	0(0.0%)	1(0.0%)	0.690
Others	pts	5(0.1%)	0(0.0%)	5(0.2%)	0.354

NICU neurointensive care unit, *ESBL* Extended spectrum beta-lactamase, *MRSA* Methicillin-resistant Staphylococcus aureus

an additional risk as a cause of secondary brain damage, which affects the morbidity and mortality of primary brain diseases [1–5]. As the aim of neurocritical care is to avoid all insults causing secondary brain damage, preventive management of nosocomial infections is a challenge for neurointensivists. Incidence of nosocomial infections can be reduced by keeping a hygienic and epidemiological regime and rational antibiotic policy. Nosocomial infection management demands constant maintenance and stable teamwork while maintaining standard procedures. We present our preventive multimodal nosocomial infection protocol, which we implemented in our NICU. The first phase involves imposing hygienic principles and the antibiotics policy. The second phase, actually keeping to this protocol, is a much more difficult task in our experience, as a vital component for its success is the participation of the whole team, from doctors and nurses to cleaners working in the neurocritical care unit and even visitors. The use of standard procedures and meticulous checks are an important part of the regime.

Here we present the impact of our preventive nosocomial infection management on the incidence of nosocomial infections in all the patients admitted to our NICU with acute brain disease. The results show that our preventive protocol was not sufficient to completely eliminate all nosocomial infections, but it did lead to a relatively low nosocomial infection incidence of 4.4%. We did not observe differences between various seasons of the year, either among primary or secondary admissions, but we did among acute admissions, acute operations and reoperations. Infections were more frequently associated with strokes than other brain diagnoses. There were significantly more infections in airways, mechanical ventilations and catheters, but only airways and urine catheters were strong predictors in multivariate logistic regression analysis. These are still risk factors which remained despite the maintenance of the preventive strategy. Further predictors were confirmed to be the well-known factors of NICU stay, wound complications, antibiotic prophylaxis and transfusion.

The increasing colonisation of multidrug-resistant bacteria ESBL and MRSA is a big problem among critically ill patients and this situation is getting worse. At present, many patients already have these bacteria on admission and this colonization constitutes a risk of nosocomial infections [16–18]. We deal with this by completely isolating these patients using barrier care techniques in order to prevent the transmission of these multidrug-resistant ESBL and MRSA to other, uncolonised patients. This was reflected in our results, which showed that we had newly occurred ESBL in only in 31 (0.9%) patients and MRSA in 30 (0.9%) patients. In this study we did not find that multidrug-resistant bacteria were a predictor of nosocomial infections.

Antibiotics policy, predominantly the overuse of antibiotics, is another big issue in preventive multimodal nosocomial infection protocol. From our results, we see

Table 8 Administration of antibiotics in NICU

Parameter	Unit	Total population *N*=3464	NI group *N*=198	Control group *N*=3266	*p* value
Antibiotic prophylaxis	pts	2183(63.0%)	127(64.1%)	2056(63.0%)	0.736
One prophylaxis	pts	1931(55.7%)	91(46.0%)	1840(56.3%)	<0.001
Operation	pts	2049(59.2%)	116(58.6%)	1933(59.2%)	0.222
Only operation theatre	pts	1157(33.4%)	61(30.8%)	1096(33.6%)	
Operation 1 dose	pts	924(26.7%)	42(21.2%)	882(27.0%)	
Operation 2 doses	pts	191(5.5%)	14(7.1%)	177(5.4%)	0.006
Operation 3 doses	pts	40(1.2%)	4(2.0%)	36(1.1%)	
Operation 4 doses	pts	2(0.1%)	1(0.5%)	1(0.0%)	
NICU	day		4.96±5.69	3.31±2.88	0.017
Others					
Aspiration	pts	51(1.5%)	5(2.5%)	46(1.4%)	0.218
Suspected infection	pts	49(1.0%)	2(1.0%)	47(1.4%)	0.600
Trauma	pts	30(1.4%)	2(1.0%)	28(0.9%)	0.844
Liquorrhoea	pts	46(0.9%)	6(3.0%)	40(1.2%)	0.034
Drainage	pts	35(1.3%)	6(3.0%)	29(0.9%)	0.004
Others	pts	31(1.0%)	4(2.0%)	27(0.8%)	0.090
NICU	Day		7.75±4.61	4.54±3.33	<0.001
Type of antibiotic					
Cefazolin	pts	1733(50.0%)	106(53.5%)	1627(49.8%)	0.242
Amoxicillin clavulanate	pts	362(10.5%)	30(15.2%)	332(10.2%)	0.028
Clindamycin	pts	127(3.7%)	5(2.5%)	122(3.7%)	0.351
Antibiotic therapy	pts	335(9.7%)	169(85.4%)	166(5.1%)	<0.001
One infection	pts	326(9.4%)	161(81.3%)	165(5.1%)	0.019
One antibiotic	pts	220(6.4%)	100(50.5%)	120(3.7%)	0.061
Two antibiotics	pts	78(2.3%)	44(22.2%)	34(1.0%)	
NICU start	pts	224(6.5%)	151(76.3%)	73(2.2%)	<0.001
Empirical therapy	pts	201(5.8%)	101(51.0%)	100(3.1%)	0.929
According to cultivation	pts	189(5.5%)	106(53.5%)	83(2.5%)	0.019
Days of ATB all	day		8.82±6.89	6.09±4.95	<0.001
Type of antibiotic					
Ceftriaxone	pts	34(1.0%)	9(4.5%)	25(0.8%)	0.003
Ceftazidime	pts	6(0.2%)	3(1.5%)	3(0.1%)	0.982
Meropenem	pts	75(2.2%)	48(24.2%)	27(0.8%)	0.008
Penicillin	pts	13(0.4%)	5(2.5%)	8(0.2%)	0.378
Oxacillin	pts	23(0.7%)	17(8.6%)	6(0.2%)	0.020
Ciprofloxacin	day	84(2.4%)	57(28.8%)	27(0.8%)	<0.001
Trimethoprim	pts	17(0.5%)	10(5.1%)	7(0.2%)	0.478
Gentamicin	pts	25(0.7%)	15(7.6%)	10(0.3%)	0.321
Others	pts	71(2.0%)	29(14.6%)	42(1.3%)	0.068

NICU neurointensive care unit, *ATB* antibiotic

that antibiotic prophylaxis is mainly used in association with operations and only 9.7% of the total population received antibiotic therapy. Unindicated use of antibiotics contributes to the emergence and spread of multidrug-resistant bacteria, which are becoming a growing problem in healthcare facilities. Antibiotics should only be given during operations and their administration should not be prolonged in the NICU. During the prophylactic use of

Table 9 Nosocomial infections on admission and onset in the NICU

Parameter	Unit	NI total	NI on admission	NI onset in NICU	*p* value
Number total	pts	198 (100%)	45 (22.7%)	153 (77.3%)	
Age	pts	57.2±15.6	53.7±16.9	58.3±15.1	0.086
Male	pts	117(59.1%)	18(40.0%)	63(41.2%)	<0.001
NICU stay	day	15.3±11.7	6.9±7.2	17.7±11.6	<0.001
Diagnoses					
Stroke	pts	110(55.6%)	13(28.9%)	97(63.4%)	
Trauma	pts	27(13.6%)	3(6.7%)	24(15.7%)	
Tumour	pts	33(16.7%)	13(28.9%)	20(13.1%)	
Epilepsy	pts	3(1.5%)	0(0.0%)	3(2.0%)	<0.001
Hydrocephalus	pts	13(6.6%)	7(15.6%)	6(3.9%)	
Infection	pts	11(5.6%)	9(20.0%)	2(1.3%)	
Others	pts	1(0.5%)	0(0.0%)	1(0.7%)	
TISS on admission		54.7±1.9	56.0±179	54.3±1.8	<0.001
TISS total		270632.8±231533.1	111173.7±231533.1	309492.6±234698.9	<0.001
GCS on admission		11.5±3.5	12.0±3.3	11.3±3.5	0.234
APACHE II on admission		15.1±5.5	13.6±5.4	15.4±5.5	0.099
GOS on NICU discharge		3.1±1.1	3.5±1.2	3.0±1.1	0.015
Mortality in NICU	pts	21(10.6%)	3(6.7%)	18(11.8%)	0.329
Operation	pts	151(76.3%)	37(82.2%)	114(74.5%)	0.285
Airways	pts	112(56.6%)	16(35.6%)	96(62.7%)	0.001
Mechanical ventilation	pts	87(43.9%)	7(15.6%)	80(52.3%)	<0.001
Artery catheter	pts	90(45.5%)	6(13.3%)	84(54.9%)	<0.001
Central venous catheter	pts	64(32.3%)	11(24.4%)	53(34.6%)	0.199
Lumbar drainage	pts	36(18.2%)	5(11.1%)	31(20.3%)	0.162
Ventricular drainage	pts	21(10.6%)	3(6.7%)	18(11.8%)	0.329
Corticoids	pts	47(23.7%)	11(24.4%)	36(23.5%)	0.899
Transfusions	pts	41(20.7%)	5(11.1%)	36(23.5%)	0.071
Ulcer prophylaxis	pts	134(67.7%)	27(60.0%)	107(69.9%)	0.210
Diabetes Mellitus	pts	22(11.1%)	3(6.7%)	19(12.4%)	0.280
Antibiotic prophylaxis	pts	127(64.1%)	23(51.1%)	104(68.0%)	0.038
Antibiotic therapy	pts	169(85.4%)	28(62.2%)	141(92.2%)	<0.001
ESBL	pts	6(3.0%)	1(2.2%)	5(3.3%)	0.719
MRSA	pts	7(3.5%)	1(2.2%)	6(3.9%)	0.587
One infection	pts	189(95.5%)	45(100.0%)	144(94.1%)	
Two infections	pts	8(4.0%)	0(0.0%)	8(5.2%)	0.250
Three infections	pts	1(0.5%)	0(0.0%)	1(0.7%)	
Bloodstream	pts	23(11.6%)	1(2.2%)	22(14.4%)	0.025
Vascular catheter	pts	14(7.1%)	1(2.2%)	13(8.5%)	0.149
Respiratory	pts	63(31.8%)	3(6.7%)	60(39.2%)	< 0.001
VAP	pts	34(17.2%)	1(2.2%)	33(21.6%)	0.002
Urinary	pts	35(17.7%)	5(11.1%)	30(19.6%)	0.189
Urinary catheter	pts	33(16.7%)	5(11.1%)	25(16.3%)	0.255
Wound without operation	pts	2(1.0%)	1(2.2%)	1(0.7%)	0.355
Wound with operation	pts	70(35.4%)	35(77.8%)	35(22.9%)	<0.001

Table 9 Nosocomial infections on admission and onset in the NICU *(Continued)*

Parameter	Unit	NI total	NI on admission	NI onset in NICU	*p* value
Wound complication					
Liquorrhoea	pts	14(7.1%)	7(15.6%)	7(4.6%)	0.012
Dehiscence	pts	11(5.6%)	9(20.0%)	2(1.3%)	<0.001
Fistula	pts	6(3.6%)	3(6.7%)	3(2.0%)	0.105

NICU neurointensive care unit, *TISS* Therapeutic Intervention Scoring System, *GCS* Glasgow Coma Scale, *APACHE* Acute Physiology and Chronic Health Evaluation, *GOS* Glasgow Outcome Scale, *ESBL* Extended spectrum beta-lactamase, *MRSA* Methicillin-resistant Staphylococcus aureus, *VAP* ventilator associated pneumonia

antibiotics it is essential not only to keep to the indication, but also to maintain the time of administration. However, this study confirmed that antibiotic prophylaxis policy is an important task, because antibiotic prophylaxis was found to be a predictor of nosocomial infection in the neurocritical care population. While using antibiotics, it is essential to maintain the correct administration and not use antibiotics during the colonisation of the patient, but only for the infection. Timing, dosage and tissue penetration are important in their administration.

Our microbiological screening was the same for all patients, who can therefore be compared easily. The unified system included nose, throat, trachea, skin, urine and rectum tests from admission, so that we would know what the patient was admitted with, and then regularly every three days. This means that this microbiological screening sometimes fell on the weekend, which at first was difficult to implement in the microbiological department. Regular microbiological screening from admission took place every three days, giving us an overview of the microbiological state of the patient and allowing us to find colonization of multidrug-resistant bacteria [18] and further perform the targeted antibiotic treatment of nosocomial infections.

Although it would be better to have single-patient boxes, the lay-out of four divided rooms provides some of the benefits and enables the isolation of patients with multidrug-resistant bacteria ESBL and MRSA, as it is very important to isolate these patients so that these bacteria do not spread to the rest of the NICU and the other patients. Our results show that over a ten-year period we did not have a large incidence of the multidrug-resistant bacteria ESBL and MRSA, while there was not a single case of VRE. This is in contrast to the Minhas [19] study, where he mentioned 2.5% of VRE in the neurosurgical and neurological intensive care unit.

This study confirmed that accesses are still a risk factor for nosocomial infection. Due to increasing numbers of invasive medical procedures in neurocritical care, local preventive infection control management has an important task. Although preventive multimodal strategy is widely known to reduce nosocomial infection and multidrug resistant bacteria, it is sometimes difficult to maintain. Nonetheless, the results of this study show the importance of this maintenance. We present our 10 year prospective infection control management, which was efficient, as it led to a rate of 4.4% nosocomial infections in acute neurological and neurosurgical care patients. Due to multiple testing, there is a higher probability of family-wise error. On the other hand, the results must be read in context, not every p-value below 0.05 is commented on as a finding.

This study showed prospective infection control management in 3464 neurocritically care patients. Although they all came from a single neurocentre, which is a limitation of this study, there are already many more epidemiologic studies regarding nosocomial infection control and multi-drug resistant bacteria from the medical and surgery intensive care units than from neurocritical care units, whether neurosurgical or neurological, and very few studies concerned with neurological-neurosurgical critical care units [19, 20]. In this area, more studies focus on specific diagnoses [1, 2, 7, 21, 22] than whole neurocritical care populations.

Table 10 Multivariate logistic regression analysis of nosocomial infection onset in NICU

Multivariate analysis				
Nosocomial infections predictors	Odds Ratio	Lower CL 95%	Upper CL 95%	*p* value
NICU stay (per day)	1.14	1.12	1.16	< 0.001
Airways	2.69	1.81	3.99	< 0.001
Urine catheter	2.77	1.00	7.70	0.050
Transfusions	1.79	1.07	2.97	0.025
Wound complications	2.30	1.33	3.97	0.003
Antibiotic prophylaxis	0.50	0.34	0.74	< 0.001

NICU neurointensive care unit, *CL* confidence limit

Conclusions

This study showed that this preventive multimodal nosocomial infection control management was efficient, because it gave low rates of nosocomial infections (4.2%), both ESBL and MRSA in a mere 0.9% of patients each and not a single case of VRE. Strong predictors for the onset of nosocomial infections were accesses such as airways and urine catheters, NICU stay, antibiotic prophylaxis, wound complications and transfusion. This study confirmed the well-known fact that nosocomial infections are associated with worse outcome, higher cost and longer NICU stay.

Abbreviations

APACHE: Acute Physiology and Chronic Health Evaluation; ASA: American Society of Anesthesiologists; ATB: antibiotic; BMI: body mass index; CRP: C-reactive protein; ESBL: Extended spectrum beta-lactamase; ETT: endotracheal tube; GCS: Glasgow Coma Scale; GOS: Glasgow Outcome Scale; ICH: intracerebral haemorrhage; MRSA: Methicillin-resistant Staphylococcus aureus; NI: nosocomial infection; NICU: neurointensive care unit; SAH: subarachnoid haemorrhage; STSP: *Staphylococcus species*; TISS: Therapeutic Intervention Scoring System; TST: tracheostomy tube; VRE: Vancomycin-resistant enterococcus

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Availability of data and materials

The datasets obtained during this study are available from the corresponding author on reasonable request.

Authors' contributions

VS, OB, DF, ZB, PS: revising it critically for important intellectual content, final approval of the manuscript, read and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. VS: conception and design, acquisition of data, interpretation of data; drafting the manuscript, OB: statistical analysis, interpretation of data, DF, ZB: acquisition of data, interpretation of data. PS: conception.

Ethics approval and consent to participate

The study was approved by the Liberec hospital Ethics Committees for Multicentric Clinical Trials (č.j. EK27/2008). All participants gave written informed consent prior to all measurements and agreed upon publication.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Publisher's Note

Author details

[1]Neurocenter, Neurointensive Care Unit, Regional Hospital, Husova 357/10, Regional Hospital, 46063 Liberec, Czech Republic. [2]Department of Neurosurgery, Military University Hospital and First Medical School, Charles University, Prague, Czech Republic. [3]Department of Clinical microbiology and immunology, Antibiotic Centre, Regional Hospital, Liberec, Czech Republic. [4]Neurocenter, Department of Neurosurgery, Regional Hospital, Liberec, Czech Republic.

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3.3. Infekce související se zdravotní péčí u onemocnění páteře

3.3.1. Risk factors of surgical site infections after thoracic and lumbar surgery: a 6-year single centre prospective cohort study. Journal of Orthopaedic Surgery and Research. 2021

Druhá habilitační práce se věnuje infekcím v místě chirurgického výkonu u pacientů po plánovaných operací hrudní a bederní páteře, kteří měli z důvodu rozsahu výkonu nebo celkového klinického stavu pooperační péči na NJ. Předností tohoto výzkumu bylo zaměření se na vliv preventivního multimodálního protokolu na výskyt SSI v jedné z nejrizikovějších oblastí páteře. Cílem práce byla analýza SSI při antibiotické profylaxi podané jen před a během operačního výkonu. Tato délka antibiotické profylaxe je cílem racionální profylaktické antibiotické politiky, a již v letech 2006 až 2010 byla realizována v rámci našeho výzkumu u velkého počtu operovaných pacientů (95,8 %).

Cílem každého operačního výkonu je eliminace nežádoucích infekčních komplikací, přičemž signifikantním prediktorem jejich vzniku jsou neinfekční komplikace v operační ráně [71], což také potvrzují naše výsledky. V našem souboru nevznikla žádná SSI bez této primární neinfekční komplikace. Tyto výsledky měly praktický dopad na našem pracovišti, byla přijata intenzivnější kontrola a péče o operační rány. Přínosem našeho výzkumu bylo zjištění i dalšího rizikového faktoru na vzniku SSI, a to teplého ročního období. Tento výsledek měl vliv nejen na naše pracoviště, zejména při plánování velkých operačních výkonů v oblasti hrudní a bederní páteře, ale toto zjištění oslovilo i tři autory k citování naší práce, Algarny (*In*

Vivo) [103], Damonti (*Journal Hospital infection*) [104] a Liu (*Annals of Translational Medicine*) [105].

Nejvíce citací se vztahuje k riziku infekčních komplikací po operacích páteře. Tyto citace autoři umístili do úvodu svých publikacích, Zhan v *International Wound Journal* [106], Liu v *BMC Surgery* [107], Cao *v International Wound Journal* [108] a Yamamoto v *Spine Journal* [109].

Výsledky této studie byly poprvé prezentovány v roce 2019 formou e-posteru na *International Symposium on Intensive Care and Emergency Medicine* v Bruselu. Součástí prezentace byl publikovaný abstrakt v *Critical Care*. Spatenkova V, Bradac O, Jindrisek Z, Hradil J, Suchomel P, Fackova M. Risk factors of surgical site infections after thoracic and lumbar surgery: a 6-year single centre prospective cohort study. Critical Care 2019 23(Suppl 2):72, s 23.

Tato výzkumná práce byla publikována v *Journal of Orthopaedic Surgery and Research*, v dobrém zahraničním recenzovaném časopise s impakt faktorem 2,677, Q2 dle SCIE v kategorii ortopedie, open access, časopisem vydávaným v nakladatelství Springer. Tato publikace má 9 citací dle WOS.

Colette Dutillieu <noreply@intensive.org>
Odesláno: pátek 4. ledna 2019 16:13

Dear Authors,

Congratulations!

We are pleased to inform you that your abstract, entitled:

' Risk factors of surgical site infections after thoracic and lumbar surgery: a 6-year single centre prospective cohort study '

has been accepted for e-poster presentation at the 39th ISICEM.

It has been assigned the number **P052.**

Poster presentations will take place on **Tuesday 19th March, 2019**, between 6 and 7 pm, in front of a jury of 3-5 experts in the field. Prizes of a total value of 5,000 Euros will be awarded for the best posters on the basis of scientific content and presentation. The awards will be presented on Thursday, **March 21, 2019** in the Gold Room at 10:00.

Your abstract will be published online in the journal *Critical Care* at the time of the Symposium.

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We look forward to meeting you in Brussels.

Yours sincerely,

Colette Dutillieu
Congress Coordinator

Risk factors of surgical site infections after thoracic and lumbar surgery: a 6-year single centre prospective cohort study

V Spatenkova[1], O Bradac[2], Z Jindrisek[1], J Hradil[3], P Suchomel[3], D Fackova[4], M Halacova[5]

[1]Regional Hospital , Neurocenter , NICU, Liberec , [2]Military University Hospital and First Medical School, Charles University, Department of Neurosurgery, Prague, [3]Regional Hospital, Neurocenter , Department of Neurosurgery, Liberec, [4]Regional Hospital, Department of Clinical microbiolog y and immunology, Antibiotic Centre, Liberec, [5]Na Homolce Hospital, Department of Clinical Pharmacology , Prague, Czech Republic

Introduction

Surgical site infection (SSI) is a risk in ev ery operation wound, as it negativ ely impacts patient morbidity and mortality , and also increases f inancial demands. The aim of this study was to analy se SSI and its risk f actors af ter thoracic and lumbar spine surgery.

Methods

A six-y ear monocentric observ ation prospectiv e cohort study monitored the incidence of SSI in 274 consecutiv epatients af ter planned thoracic and lumbar surgery f or degenerativ e disease, trauma and tumour. All patients receiv ed short antibiotic prophy laxis (bef ore and during long operations). SSI was classif iedas 1/ superf iciat skin and subcutaneous tissue, 2/ deep, f asciaand muscle, 3/ organ: organs and spaces. In superf icialSSI without microbiology we added borderline cases which we def ined as big serom or spontaneous dehisces with secretion and high CRP, local or sy stemicantibiotic therapy. The incidence of SSI was monitored up to 30 day s and 1 y ear af ter operations. We searched f or risk f actors f or SSI in multiv ariatelogistic regression analy sis.

Results

Ov er six y ears we recorded 22 incidences of SSI (8.03%),mostly these were superf icial(5.84%), and f ewer were deep (1.82%) and organ (0.36%).

Demographic and clinical data	Unit	Total population N=274	Control group N=252	SSI N=22	p value
Age	pts		54.06 ±12.89	56.59 ±13.18	0.374
Male	pts	145 (52.92%)	132 (52.38%)	13 (59.09%)	0.545
Weight	kg		80.72 ±14.94	79.36 ±15.05	0.668
BMI			27.48 ±4.00	27.69 ±4.17	0.878
NICU stay	day		1.61 ±1.10	1.32 ±1.51	0.043
Hospital stay	day		8.65 ±5.92	11.55 ±6.35	0.094
Cold season	pts	210 (76.64%)	197 (78.17%)	13 (59.09%)	0.042
Warm season	pts	64 (23.36%)	55 (21.83%)	9 (40.91%)	
Spine diagnoses					
Degenerativ e	pts	247 (90.15%)	227 (90.08%)	20 (90.91%)	
Tumour	pts	21 (7.66%)	19 (7.54%)	2 (9.09%)	0.745
Trauma	pts	6 (2.19%)	6 (2.19%)	0 (0.00%)	
Diabetes Mellitus	pts	33 (12.04%)	30 (11.90%)	3 (13.64%)	0.811
Ulcer prophy laxis	pts	56 (20.44%)	53 (21.03%)	3 (13.64%)	0.409
Omeprazole	pts	50 (18.25%)	47 (18.65%)	3 (13.64%)	0.559

Demographic and clinical data	Unit	Total population N=274	Control group N=252	SSI N=22	p value
1-dose operation	pts	145 (52.92%)	133 (52.78%)	12 (54.55%)	
2-dose operation	pts	122 (44.53%)	112 (44.44%)	10 (45.45%)	0.731
3-dose operation	pts	7 (2.55%)	7 (2.78%)	0 (0.00%)	
Cefazolin	pts	245 (89.42%)	225 (89.29%)	20 (90.91%)	0.812
Clindamycin	pts	27 (9.85%)	25 (9.92%)	2 (9.09%)	0.900
Amoxicillin Clav ulanate	pts	2 (0.73%)	2 (0.79%)	0 (0.00%)	0.675

Operation	Unit	Total population N=274	Control group N=252	SSI N=22	p value
Localization					
Th	pts	26 (9.49%)	23 (9.13%)	3 (13.64%)	
Th-L	pts	2 (0.73%)	2 (0.79%)	0 (0.00%)	0.808
L	pts	130 (47.45%)	118 (46.83%)	12 (54.55%)	
LS	pts	116 (42.34%)	109 (43.25%)	7 (31.82%)	
ASA score			2.14 ±0.68	2.18 ±0.71	0.752
Reoperation	pts	27 (9.85%)	27 (10.71%)	0 (0.00%)	0.106
Time of operation	minutes		184.16 ±72.23	173.86 ±81.48	0.547
Implant	pts	239 (87.23%)	221 (87.70%)	18 (81.82%)	0.428
Drainage					
Transfusions	pts	49 (17.88%)	47 (18.65%)	2 (9.09%)	0.262
Blood loss	ml		1027.82 ±968.97	747.37 ±1234.82	0.106
Haemoglobin			103.45 ±20.05	105.36 ±20.50	0.548
Corticoids	pts	26 (9.49%)	25 (9.92%)	1 (4.55%)	0.409
Methylprednisolone	pts	5 (1.82%)	5 (1.82%)	0 (0.00%)	0.505
Hydrocortisone	pts	18 (6.57%)	17 (6.75%)	1 (4.55%)	0.689
Postoperative NICU					
TISS on admission			57.21 ±1.01	57.36 ±1.06	0.526
APACHE II			9.62 ±3.29	9.14. ±3.40	0.455
Urine catheter	pts	263 (95.99%)	243 (96.43%)	20 (90.91%)	0.423
Hospital wound complications	pts	27 (9.85%)	15 (5.95%)	12 (54.55%)	<0.001

Multivariete logistic regression analysis of SSI (CL – confidence limit)

	Odds Ration	Lower CL 95%	Upper CL 95%	p value
Hospital wound complication	20.40	7.32	56.85	<0.001
Warm season	2.92	1.03	8.27	0.044

No.	SSI	Occurrence interval	Wound complication	Microbiology
1	Superficial	30 days	Dehiscence	0
2	Superficial	30 days	Dehiscence	0
3	Superficial	30 days	Dehiscence	0
4	Superficial	30 days	Secretion	0
5	Superficial	30 days	Dehiscence	Staphylococcus aureus Methicillin-sensitive
6	Superficial	30 days	Dehiscence	0
7	Superficial	30 days	Dehiscence	Staphylococcus aureus Methicillin-sensitive
8	Superficial	30 days	Dehiscence	Staphylococcus aureus Methicillin-sensitive, Streptococcus viridans
9	Superficial	30 days	Dehiscence	0
10	Superficial	30 days	Dehiscence	Staphylococcus aureus Methicillin-sensitive, Peptococcus Peptostreptococcus,
11	Superficial	30 days	Secretion	0
12	Superficial	30 days	Secretion	Negative
13	Superficial	30 days	Dehiscence	Staphylococcus aureus Methicillin-sensitive, Klebsiella pneumoniae
14	Superficial	30 days	Seroma	0
15	Superficial	30 days	Dehiscence	Staphylococcus aureus Methicillin-sensitive
16	Superficial	30 days	Dehiscence	Streptococcus alfa, Propionibacterium
17	Deep	30 days	Dehiscence	Staphylococcus Coagulase-negative
18	Deep	30 days	Dehiscence	Enterococcus faecalis, Pseudomonas aeruginosa, Peptostreptococcus
19	Deep	30 days	Secretion	Staphylococcus aureus Methicillin-sensitive, Acinetobacter baumanii
20	Deep	1 year	Secretion	Staphylococcus aureus Methicillin-sensitive
21	Deep	30 days	Dehiscence	0
22	Organ	30 days	Hematoma	Staphylococcus Coagulase-negative

Conclusion

Contrary to the prev ailing literature, our study on a population of planned thoracic and lumbar spine surgery patients with short antibiotic prophy laxis hospitalized postoperativ ely in the NICU did not identif y corticosteroids, diabetes mellitus or transf usionsas risk f actorsf or SSI. This study only confirmed that any kind of non-inf ectious wound complication and operations in the warm season are independent risk f actorsf or dev eloping such inf ections.

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RESEARCH ARTICLE Open Access

Risk factors associated with surgical site infections after thoracic or lumbar surgery: a 6-year single centre prospective cohort study

Vera Spatenkova[1*], Ondrej Bradac[2], Zdenek Jindrisek[1], Jan Hradil[3], Daniela Fackova[4] and Milada Halacova[5]

Abstract

Background: Surgical site infection (SSI) is a risk in every operation. Infections negatively impact patient morbidity and mortality and increase financial demands. The aim of this study was to analyse SSI and its risk factors in patients after thoracic or lumbar spine surgery.

Methods: A six-year single-centre prospective observational cohort study monitored the incidence of SSI in 274 patients who received planned thoracic or lumbar spinal surgery for degenerative disease, trauma, or tumour. They were monitored for up to 30 days postoperatively and again after 1 year. All patients received short antibiotic prophylaxis and stayed in the eight-bed neurointensive care unit (NICU) during the immediate postoperative period. Risk factors for SSI were sought using multivariate logistic regression analysis.

Results: We recorded 22 incidences of SSI (8.03%; superficial 5.84%, deep 1.82%, and organ 0.36%). Comparing patients with and without SSI, there were no differences in age (p=0.374), gender (p=0.545), body mass index (p=0.878), spine diagnosis (p=0.745), number of vertebrae (p=0.786), spine localization (p=0.808), implant use (p=0.428), American Society of Anesthesiologists (ASA) Score (p=0.752), urine catheterization (p=0.423), drainage (p=0.498), corticosteroid use (p=0.409), transfusion (p=0.262), ulcer prophylaxis (p=0.409) and diabetes mellitus (p=0.811). The SSI group had longer NICU stays (p=0.043) and more non-infectious hospital wound complications (p<0.001). SSI risk factors according to our multivariate logistic regression analysis were hospital wound complications (OR 20.40, 95% CI 7.32–56.85, p<0.001) and warm season (OR 2.92, 95% CI 1.03–8.27, p=0.044).

Conclusions: Contrary to the prevailing literature, our study did not identify corticosteroids, diabetes mellitus, or transfusions as risk factors for the development of SSI. Only wound complications and warm seasons were significantly associated with SSI development according to our multivariate regression analysis.

Keywords: Surgical site infection, Preventive infection protocol, Wound complications, Antibiotic prophylaxis, Spine surgery

* Correspondence: vera.spatenkova@nemlib.cz
[1]Neurocenter, Neurointensive Care Unit, Regional Hospital, Husova 357/10, 46063 Liberec, Czech Republic
Full list of author information is available at the end of the article

Background

Every surgery carries a risk of SSI, a complication which negatively impacts patient morbidity and mortality, increases financial demands by prolonging hospital stay, and may require further antibiotics and surgical procedures. SSIs are a significant group of healthcare-associated infections with high preventability [1, 2]. Prudent preventive strategies have an important role in increasing postoperative patient safety and can limit the incidence of multidrug resistant strains. The elimination of this complication is a priority in all surgical management and is particularly important in spine operations, where these risks are heightened due to the frequent use of metallic implants, the nearby localization of the spinal cord, and the load-bearing function of the spine. The incidence of SSI in spine surgery varies from 2 to 13% according to literature of varying quality and methodology [3–10]. A protective protocol includes many strategies for reducing the risk of developing an SSI. This involves maintaining correct antibiotic prophylaxis, and proper hygiene throughout all stages of surgery and general care, not only in the operating theatre but crucially during the postoperative period until the wound has healed [1, 2].

The aim of this study was to identify and analyse SSI in accordance with international definitions, and to search for risk factors associated with its onset in patients who had undergone thoracic or lumbar spine surgery.

Method

A 6-year single-centre prospective observational cohort study was conducted in the Neurocenter at the 900-bed Liberec Regional Hospital from 1 January 2005 to 31 December 2010. The incidence of SSI was monitored in 274 who fulfilled our inclusion criteria. These criteria were (1) planned operation; (2) thoracic or lumbar localization; (3) degenerative disease, trauma, or tumour; (4) short antibiotic prophylaxis defined as antibiotic administration before surgery and during long operations; and (5) patients who were recommended by neurosurgeons or anaesthetists for a postoperative stay in the eight-bed Neuro-intensive Care Unit (NICU) which has a multimodal preventive infection control and normoglycemia protocol. Exclusion criteria were as follows: (1) primary infection of the spine and (2) prolonged antibiotic prophylaxis defined as continued antibiotic administration before and/or after the operation.

SSIs were classified according to Horan et al. [11] as (1) superficial: skin and subcutaneous tissue; (2) deep: fascia and muscle; and (3) organ: organs and spaces. For superficial SSI without microbiology we included borderline cases. These were defined as either a large seroma, or spontaneous dehiscence with secretion and high CRP. Borderline cases were treated with local or systemic antibiotic therapy. The incidence of SSI was monitored for up to 30 days postoperatively and again after 1 year. The following prevention protocols were adhered to in order to conduct SSI analysis. Hygiene rules: (1) hand hygiene before and after patient contact and each procedure; (2) masks, surgical caps, sterile surgical gowns, and sterile insertion of systems in invasive medical procedures; (3) disinfection soap before entering the operating theatre; (4) principles for drainage and tubes: single-use products, closed systems, minimal necessary duration, minimal and only necessary disconnection using the port system, and regular and irregular exchange according to protocol; and (5) surgical wound fully covered and dry.

Antibiotic prophylaxis: We mainly used two types of antibiotics without rotation. The first choice antibiotic was cefazolin; in case of allergy, clindamycin was used.

(1) Short prophylaxis: Administered before and during the operation, without prolonging use after the operation. (2) Doses: Intravenous administration of the appropriate dose of antibiotics. In patients up to 120 kg either 2 g of cefazolin or 600 mg of clindamycin, over 120 kg either 3 g of cefazolin or 900–1200 mg of clindamycin, with repeated administration during high blood loss (over 1.5 l blood). (3) Timing: The correct timing before incision (30–60 min) and perioperative administration at the correct interval (cefazolin at 4 h, clindamycin without need for further administration) [1]. We studied the following risk factors of SSI: (1) parameters associated with operations (localization, number of vertebrae, reoperation, time of operation, use of graft and implant, ASA Score); (2) use of medical devices: drainage, airways, mechanical ventilation, and catheters (artery, central venous, urine); (3) administration of corticosteroids (methylprednisolone, hydrocortisone); (4) transfusions, blood loss, and haemoglobin; (5) ulcer prophylaxis; (6) diabetes mellitus; (7) Acute Physiology and Chronic Health Evaluation (APACHE) II score on admission; (8) C-reactive protein (CRP); (9) length of stay in the NICU and in our hospital; (10) non-infectious hospital wound complications; and (11) warm season (June, July, August).

Statistical analysis

Parametric *t*-tests or non-parametric Mann-Whitney *U* tests were used for comparison of continuous parameters. Comparison of categorical parameters was carried out using chi-square or Fisher's tests as appropriate. Univariate logistic regression was used for identifying prognostic factors of wound complications. Factors from our univariate analysis that met the significance threshold of $p < 0.1$ were used for multivariate regression analysis; factors with p value <0.1 were left in the model. P values of less than 0.05 were considered significant. STATISTICA 13.2 (TIBCO Software Inc., Palo Alto, CA, USA) software was used for statistical analyses.

The study was conducted after the approval of the Regional Hospital Ethics Committee for Multicentric Clinical Trials.

Results

Of 286 consecutive patients treated at our centre, 274 met our inclusion criteria and were included in our study. We excluded twelve patients due to their prolonged antibiotic prophylaxis following the operation. The results of short antibiotic prophylaxis are shown in Table 1.

Over 6 years, we recorded 22 incidences of SSI (8.03%), the majority were superficial (5.84%), and a few were deep (1.82%) or organ (0.36%). When patients with SSI were compared with the control group, there were no significant differences in demographic data, diabetes mellitus, or ulcer prophylaxis (Table 2). There was also no difference concerning corticosteroid use. The mean duration of corticosteroid use was 2.14±1.17 days. Results associated with operations are shown in Table 3. No differences were found in localization, number of vertebrae, duration of operation, or any other parameter associated with operations. Similarly, non-significant results were found in parameters associated with the immediate postoperative period in the NICU.

However, in the SSI group, we found more wound complications of other etiologies (such as dehiscence, secretion, seroma, or haematoma) (Table 4). These complications together with incidence during the warm season (June, July, and August) were found to be the only significant predictors of SSI according to our multivariate logistic regression analysis (Table 5).

Discussion

The incidence of SSI is an important mark of quality management in every surgical procedure. Since these infections are preventable, it is important to take an interest in their monitoring [2]. SSIs can worsen the final results of operations, and additionally in spinal surgery, a patient's mobility can be affected due to the close proximity of the spinal cord and neural structures. This will raise the costs of care for the spine operation.

Since new therapeutic approaches are limited, the basis of SSI management is prevention. This means maintaining an aseptic environment, a standard which is followed closely in the operating theatre. This standard is also important throughout every stage of the postoperative period, and especially in the initial phase until the wound has healed.

The biggest challenge to the implementation of a preventative care protocol is compliance of the entire team of doctors, nurses, and technicians.

An important component of our SSI prevention strategy was the correct antibiotic prophylaxis [1]. Antibiotic prophylaxis is based on the principle of eliminating any bacterial contaminant by administering a suitable antibiotic so that it is present in the surgical site, even in blood clots, in an effective bactericidal concentration throughout the entire operation. One common mistake which has significant epidemiological consequences is the inappropriate prolongation of antibiotic prophylaxis. All our prophylaxes were short-term, with the exception of 12 (4.20%) of our 286 consecutive patients, who received prolonged antibiotic prophylaxis. These 12 patients were excluded from our study for this reason. Another common error that substantially impairs the effectiveness of antibiotic prophylaxis is the incorrect timing of preoperative administration. We resolved this issue by giving antibiotics immediately in the preoperative prep-room, thus achieving the appropriate level of protection at the time of incision. Last but not least, failure to administer appropriate doses when operations are prolonged can result in excessive or insufficient prophylaxis.

To interpret the quality and effectiveness of antibiotic prophylaxis properly, patient populations should be stratified according to risk and outcomes, and interpretation should take into account the influence of other risk factors. For each procedure, process indicators and audit methodology should be defined in the quality assessment of antibiotic prophylaxis. In order to draw a statistically meaningful conclusion, a minimum of 100 homogenous procedures should be evaluated. Our study population of 274 patients (defined by 6-year period) fulfils this criterion with a high safety margin. For each operation, the

Table 1 Antibiotic prophylaxis

Parameter	Unit	Total population *N*=274	Control group *N*=252	SSI *N*=22	*p* value
1-Dose operation	pts	145 (52.92%)	133 (52.78%)	12 (54.55%)	
2-Dose operation	pts	122 (44.53%)	112 (44.44%)	10 (45.45%)	0.731
3-Dose operation	pts	7 (2.55%)	7 (2.78%)	0 (0.00%)	
Cefazolin	pts	245 (89.42%)	225 (89.29%)	20 (90.91%)	0.812
Clindamycin	pts	27 (9.85%)	25 (9.92%)	2 (9.09%)	0.900
Amoxicillin-clavulanate	pts	2 (0.73%)	2 (0.79%)	0 (0.00%)	0.675

Table 2 Demographic and clinical data of spine surgery patients

Parameter	Unit	Total population	Control group	SSI	*p* value
Number total	pts	274 (100%)	252 (91.97%)	22 (8.03%)	
2005	pts	37 (13.50%)	33 (13.10%)	4 (18.18%)	
2006	pts	46 (16.79%)	41 (16.27%)	5 (22.73%)	
2007	pts	34 (12.41%)	30 (11.90%)	4 (18.18%)	0.746
2008	pts	47 (47.15%)	44 (17.46%)	3 (13.64%)	
2009	pts	57 (20.80%)	54 (21.43%)	3 (13.64%)	
2010	pts	53 (19.34%)	50 (19.84%)	3 (13.64%)	
January	pts	31 (11.31%)	29 (11.51%)	2 (9.09%)	
February	pts	18 (6.57%)	15 (5.95%)	3 (13.64%)	
March	pts	36 (13.14%)	35 (13.89%)	1 (4.55%)	
April	pts	25 (9.12%)	23 (9.13%)	2 (9.09%)	
May	pts	20 (7.30%)	19 (7.54%)	1 (4.55%)	
June	pts	22 (8.03%)	20 (7.94%)	2 (9.09%)	
July	pts	15 (5.47%)	12 (4.76%)	3 (13.64%)	
August	pts	27 (9.85%)	23 (9.13%)	4 (18.18%)	
September	pts	22 (8.03%)	21 (8.33%)	1 (4.55%)	
October	pts	27 (9.85%)	25 (9.92%)	2 (9.09%)	
November	pts	21 (7.66%)	20 (7.94%)	1 (4.55%)	
December	pts	10 (3.65%)	10 (3.97%)	0 (0.00%)	
Cold season	pts	210 (76.64%)	197 (78.17%)	13 (59.09%)	
Warm season	pts	64 (23.36%)	55 (21.83%)	9 (40.91%)	**0.042**
Age	pts		54.06±12.89	56.59±13.18	0.374
Male	pts	145 (52.92%)	132 (52.38%)	13 (59.09%)	0.545
Weight	kg		80.72±14.94	79.36±15.05	0.668
BMI			27.48±4.00	27.69±4.17	0.878
NICU stay	day		1.61±1.10	1.32±1.51	**0.043**
Hospital stay	day		8.65±5.92	11.55±6.35	0.094
Spine diagnoses					
Degenerative	pts	247 (90.15%)	227 (90.08%)	20 (90.91%)	
Tumour	pts	21 (7.66%)	19 (7.54%)	2 (9.09%)	0.745
Trauma	pts	6 (2.19%)	6 (2.19%)	0 (0.00%)	
Diabetes mellitus	pts	33 (12.04%)	30 (11.90%)	3 (13.64%)	0.811
Ulcer prophylaxis	pts	56 (20.44%)	53 (21.03%)	3 (13.64%)	0.409
Omeprazole	pts	50 (18.25%)	47 (18.65%)	3 (13.64%)	0.559

BMI body mass index, *NICU* neurointensive care unit. Warm season—June to August; cold season—January to May, September to December

patient's weight, antibiotic administered, route of administration, dose rate, exact time of dosing, time and extent of any additional doses during the operation, time of the end of the operation, overall length of the operation, and the number of doses of antibiotic administered at the end of the procedure were recorded.

Incidence of SSI in spine surgery varies from 2 to 13% [3–10]. This wide variation is because a large proportion of the studies are of a retrospective design, the criteria for the definition of SSI is inconsistent, and a lack of meticulous reporting, as cited in *Spine* (Boody and Vaccaro, 43) [9]. Our results are based on prospectively collected data, a consecutive population, and the internationally accepted definition of SSI according to Horan et al. [11]. During this 6-year monitoring period, we identified 22 patients with SSI, which is at the upper limit (8.03%) of the results reported in literature. However, we emphasize that we included every single incidence of SSI, including borderline cases; we decided to include these due to our experience of non-purulent secretion with positive microbiology.

Table 3 Characteristics of spine surgery

Operation	Unit	Total population N=274	Control group N=252	SSI N=22	p value
Localization					
Th	pts	26 (9.49%)	23 (9.13%)	3 (13.64%)	
Th-L	pts	2 (0.73%)	2 (0.79%)	0 (0.00%)	0.808
L	pts	130 (47.45%)	118 (46.83%)	12 (54.55%)	
LS	pts	116 (42.34%)	109 (43.25%)	7 (31.82%)	
Number of vertebrae			2.30±0.90	2.36±1.10	0.786
0–2	pts	202 (73.72%)	16 (66.67%)	199 (71.07%)	
3–4	pts	62 (22.63%)	57 (22.62%)	5 (22.73%)	0.972
5 and more	pts	10 (3.65%)	9 (3.57%)	1 (4.55%)	
ASA score			2.14±0.68	2.18±0.71	0.752
Reoperation	pts	27 (9.85%)	27 (10.71%)	0 (0.00%)	0.106
Time of operation	minutes		184.16±72.23	173.86±81.48	0.547
Operation access					
Anterior	pts	7 (2.56%)	1 (4.17%)	7 (2.51%)	
Posterior	pts	261 (95.60%)	240 (87.91%)	6 (3.395%)	0.938
Graft	pts	5 (1.82%)	5 (1.98%)	0 (0.00%)	0.505
Implant	pts	239 (87.23%)	221 (87.70%)	18 (81.82%)	0.428
Drainage					
Redon	pts	258 (94.16%)	238 (94.44%)	20 (90.91%)	0.498
One drainage	pts	61 (23.64%)	57 (23.95%)	4 (20.00%)	0.690
Two and more drainage	pts	197 (76.36%)	181 (76.05%)	16 (80.00%)	
Transfusions	pts	49 (17.88%)	47 (18.65%)	2 (9.09%)	0.262
Blood loss	ml		1027.82±968.97	747.37±1234.82	0.106
Haemoglobin			103.45±20.05	105.36±20.50	0.548
Corticoids	pts	26 (9.49%)	25 (9.92%)	1 (4.55%)	0.409
Methylprednisolone	pts	5 (1.82%)	5 (1.82%)	0 (0.00%)	0.505
Hydrocortisone	pts	18 (6.57%)	17 (6.75%)	1 (4.55%)	0.689
Postoperative NICU					
TISS on admission			57.21±1.01	57.36±1.06	0.526
TISS total			11593.22±11693.03	38364.64±42240.21	0.383
APACHE II			9.62±3.29	9.14.±3.40	0.455
CRP			3.41±9.02	2.33±14.58	0.130
CRP 1 day after OP			35.66±19.97	38.89±24.24	0.541
Airways	pts	1 (0.36%)	1 (0.40%)	0 (0.00%)	0.767
Mechanical ventilation	pts	1 (0.36%)	1 (0.40%)	0 (0.00%)	0.767
Artery catheters	pts	32 (11.68%)	29 (11.51%)	3 (13.64%)	0.766
Central venous catheter	pts	2 (0.73%)	2 (0.73%)	0 (0.00%)	0.675
Urine catheter	pts	263 (95.99%)	243 (96.43%)	20 (90.91%)	0.423
Hospital wound complications	pts	27 (9.85%)	15 (5.95%)	12 (54.55%)	**<0.001**

ASA American Society of Anesthesiologists, *NICU* neurointensive care unit, *TISS* Therapeutic Intervention Scoring System, *APACHE* Acute Physiology and Chronic Health Evaluation, *CRP* C-reactive protein, *OP* operation

This result reflects genuine evaluation and accurate reporting. The vast majority of complications were classified as superficial and there were very few deep (1.82%) and organ complications (0.36%). Since all infections in the wound (22 patients) were preceded by a non-infective wound complication, it is evident that these complications, which had

Table 4 Characteristics of surgical site infection

Number	SSI	Occurrence interval	Wound complication	Microbiology
1	Superficial	30 days	Dehiscence	0
2	Superficial	30 days	Dehiscence	0
3	Superficial	30 days	Dehiscence	0
4	Superficial	30 days	Secretion	0
5	Superficial	30 days	Dehiscence	*Staphylococcus aureus Methicillin-sensitive*
6	Superficial	30 days	Dehiscence	0
7	Superficial	30 days	Dehiscence	*Staphylococcus aureus Methicillin-sensitive*
8	Superficial	30 days	Dehiscence	*Staphylococcus aureus Methicillin-sensitive, Streptococcus viridans*
9	Superficial	30 days	Dehiscence	0
10	Superficial	30 days	Dehiscence	*Staphylococcus aureus Methicillin-sensitive, Peptococcus Peptostreptococcus,*
11	Superficial	30 days	Secretion	0
12	Superficial	30 days	Secretion	Negative
13	Superficial	30 days	Dehiscence	*Staphylococcus aureus Methicillin-sensitive, Klebsiella pneumoniae*
14	Superficial	30 days	Seroma	0
15	Superficial	30 days	Dehiscence	*Staphylococcus aureus Methicillin-sensitive*
16	Superficial	30 days	Dehiscence	*Streptococcus alfa, Propionibacterium*
17	Deep	30 days	Dehiscence	*Staphylococcus Coagulase-negative*
18	Deep	30 days	Dehiscence	*Enterococcus faecalis, Pseudomonas aeruginosa, Peptostreptococcus*
19	Deep	30 days	Secretion	*Staphylococcus aureus Methicillin-sensitive, Acinetobacter baumanii*
20	Deep	1 year	Secretion	*Staphylococcus aureus Methicillin-sensitive*
21	Deep	30 days	Dehiscence	0
22	Organ	30 days	Haematoma	*Staphylococcus coagulase-negative*

various causes including the quality of wound care, are a significant risk factor. Established procedural methods in the preoperative and perioperative period confirm a high degree of preventability of SSI [2]. For this reason, it is important to carefully monitor all such non-infectious wound complications.

Another significant factor (in fact a leading factor in cases of delayed SSI) appears to be patient compliance. However, this factor is extremely hard to describe using numerical methods and it was not evaluated in our study.

Contrary to the prevailing conclusions in literature [12–15], some of the anticipated risk factors were not confirmed by our study, namely diabetes mellitus, the use of corticosteroids, transfusions, or ulcer prophylaxis. Concerning diabetes mellitus, we attribute the result to our strict maintenance of normoglycemia in our patients. Two reasons for the insignificant influence of corticosteroids as a risk factor may be the short duration of immunosuppressive therapy during the preoperative and postoperative period (mean duration was 2.14±1.17 days) and the size of the dose administered. The prevailing corticosteroid was hydrocortisone in a substitute dose (150–300 mg), which was not indicated as a risk factor for SSI in the results. The insignificant influence of transfusions can probably be attributed to our transfusion strategy with a low trigger of haemoglobin levels (70 g/L), which resulted in fewer transfusion cases. This study found that besides non-infectious wound complications as a general category, the only significant risk factor was operation during the warm season, in our region from June to August. In these months, the local average temperature is 20.9°C in June, and 18.7 in both July and August. The reason for an increase in SSI during the warm season is primarily due to the lack of

Table 5 Multivariate logistic regression analysis of surgical site infections (*CL* confidence limit)

Multivariate analysis				
Surgical site infections	**Odds ratio**	**Lower CL 95%**	**Upper CL 95%**	***p* value**
Hospital wound complication	20.40	7.32	56.85	<0.001
Warm season	2.92	1.03	8.27	0.044

air-conditioning in our wards at the time of the study. The higher ambient temperature during the summer leads to increased sweating of the skin and results in less favourable conditions for wound healing, requiring more frequent re-dressing of the wound. Skin irritation is more likely, leading to decreased compliance by some patients (keeping the dressings clean and avoiding mechanical stimuli to the wound). However, this explanation is purely observational, as such factors are nearly impossible to evaluate numerically.

There is a slight increase in the rate of SSI during January and February. We did not identify any objective factors for such an increase. The only possible explanation we could think of is speculative in its nature. Considering our system of reimbursement, the surgeons always face restrictions of budget and resources at the end of the fiscal year. They admitted they tend to operate on patients with more favourable radiological findings and less risk in general terms during December. They also tend to postpone more difficult cases to the beginning of the new fiscal year. Such selection is based on personal, nonparametric experience and subjective evaluation. Our assumption is further supported by zero SSI during the final month of the year; however, we have no means for any kind of numerical evaluation.

Our study has several limitations. We do not evaluate some factors of potential significance, namely smoking and nutrition. Despite the majority of elective operations, these factors cannot be assessed properly due to lack of data on admission and the short period before surgery. All the patients had glucose values tested during the period before the operation; however, immediate preoperative values were measured only in patients with diabetes mellitus.

Conclusions

Contrary to the prevailing literature, our study on a population of planned thoracic or lumbar spine surgery patients with short antibiotic prophylaxis hospitalized postoperatively in the NICU did not identify corticosteroids, diabetes mellitus, or transfusions as risk factors for SSI. Our study concludes that any kind of non-infectious wound complication and operation during the warm season represent independent risk factors for developing such infections.

Abbreviations

APACHE: Acute Physiology and Chronic Health Evaluation; ASA: American Society of Anesthesiologists; BMI: Body mass index; CL: Confidence limit; CRP: C-reactive protein; NICU: Neurointensive care unit; OP: Operation; SSI: Surgical site infection; TISS: Therapeutic Intervention Scoring System

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Authors' contributions

VS: Conception and design, acquisition and interpretation of data; drafting and final approval of the manuscript; OB: statistical analysis, interpretation of data; ZJ: acquisition of data; JH: acquisition and interpretation of data, drafting and final approval of the manuscript; DF: acquisition and interpretation of data; MH: interpretation of data. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets obtained during this study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the Liberec Hospital Ethics Committees for Multicentric Clinical Trials No. 27. All participants gave written informed consent prior to all measurements and agreed upon publication.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no conflicts of interest.

Author details

[1]Neurocenter, Neurointensive Care Unit, Regional Hospital, Husova 357/10, 46063 Liberec, Czech Republic. [2]Department of Neurosurgery, Military University Hospital and First Medical School, Charles University, Prague, Czech Republic. [3]Neurocenter, Department of Neurosurgery, Regional Hospital, Liberec, Czech Republic. [4]Department of Clinical microbiology and immunology, Antibiotic Centre, Regional Hospital, Liberec, Czech Republic. [5]Department of Clinical Pharmacology, Na Homolce Hospital, Prague, Czech Republic.

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Publisher's Note

3.3.2. Incidence of surgical site infections after cervical spine surgery: Results of a 6-year single center prospective cohort study adhering to multimodal preventive wound control protocol. The European Journal of Orthopaedic Surgery and Traumatology. 2022

Třetí habilitační práce se také věnovala infekcím v místě chirurgického výkonu po operacích páteře, ale předmětem výzkumu byly operace krční páteře z předního a zadního operačního přístupu. Význam této práce spočívá v analýze velkého souboru pacientů, u kterých byla realizována antibiotické profylaxe jen před a během operačního výkonu. Výsledky této práce jednoznačně poukazují, že tato délka antibiotické profylaxe je dostatečná. Tento výzkum současně potvrdil, že tyto operace krční páteře patří z hlediska výskytu infekčních komplikací mezi nejméně rizikové operace v oblasti páteře a že ve shodě s literaturou zadní operační přístup je rizikovější než přední [96].

V našem výzkumném souboru se vyskytly pouze dvě SSI, a obě vznikly v souvislosti s neinfekční komplikaci v operační ráně. Tato práce opět potvrdila, že primární neinfekční komplikace v operační ráně představují vysoké riziko SSI. Na základě těchto výsledků došlo k další zpřísnění protokolu péče o operační ránu na našem pracovišti.

Předložená publikace v *The European Journal of Orthopaedic Surgery and Traumatology* má dle WoS 3 citace. Nejvyšší hodnotu má citace v Lerchově metaanalýze o vlivu drenáží u předních operacích krční páteře publikovaná v *British Journal of Neurosurgery* [97]. V této publikaci máme současně poděkování v Acknowledgments za poskytnutí primárních dat. Pro potvrzení rizika zadního operačního přístupu u operacích krční páteře je citována naše práce v úvodu Wangově

publikaci z roku 2023 v časopise *International Wound Journal* [110]. Nízká incidence SSI v naší práci zaujala Zielińskou v jejím review z roku 2023 v časopise *International Journal of Molecular Sciences* [111].

Tato výzkumná práce byla publikována v *The European Journal of Orthopaedic Surgery and Traumatology*, v dobrém zahraničním recenzovaném ortopedickém časopise ve WOS, Q3 dle ESCI v kategorii ortopedie, s impakt faktorem 1,400, open access a časopisem vydávaným v nakladatelství Springer.

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ORIGINAL ARTICLE

Incidence of surgical site infections after cervical spine surgery: results of a single-center cohort study adhering to multimodal preventive wound control protocol

Vera Spatenkova[1,2,3,4] · Ondrej Bradac[5] · Zuzana Mareckova[6] · Petr Suchomel[4,6] · Jan Hradil[6] · Eduard Kuriscak[3] · Milada Halacova[7]

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Abstract

Purpose The incidence of surgical site infections is considered a relevant indicator of perioperative and postoperative care quality. The aim of this study is to analyze and evaluate SSIs after elective cervical spine surgery under the guidance of our preventive multimodal wound protocol.

Methods A monocentric observational cohort study analyzed 797 patients who underwent cervical spine surgery from 2005 to 2010 (mean age 51.58 ± 11.74 year, male 56.09%, mean BMI 26.87 ± 4.41, ASA score 1–2 in 81.68% of patients), fulfilling the entry criteria: (1) cervical spine surgery performed by neurosurgeons (degenerative disease 85.19%, trauma 11.04%, tumor 3.76%), (2) elective surgery, (3) postoperative care in our neurointensive care unit. Our preventive wound control protocol management focused mainly on antibiotic prophylaxis, wound hygiene regime, and drainage equipment. All wound complications and surgical site infections were monitored up for 1 year after surgery.

Results We had only 2 (0.25%) patients with SSI after cervical spine surgery—one organ/space infection (osteomyelitis, primary due to liquorrhea) after anterior surgical approach, and one deep surgical site infection (due to dehiscence) after posterior approach. We had 17 (2.13%) patients with some wound complications (secretion 7, dehiscence 4, hematoma 1, edema 3, and liquorrhea 2) that were not classified as SSI according to the CDC guidelines.

Conclusion Concerning our study population of patients undergoing elective cervical surgery, with ASA scores 1–2 in 81.68% of our patients, the incidence of SSI was 0.14% after anterior surgical approach, 1.4% after posterior surgical approach, and 0.25% altogether in the referred cohort.

Keywords Surgical site infection · Incidence of SSI · Preventive infection protocol · Wound complications · Antibiotic prophylaxis

Introduction

A surgical site infection (SSI) is an infection that occurs after surgery in parts of the body where the surgery takes place. SSIs are defined and classified by the CDC guidelines [1]. SSIs are caused by various factors ranging from those related to patient characteristics, to factors that depend on the hospital and the care provided there [2]. Conditions of patients before surgery such as fever, higher CRP, alcoholism, age, comorbidities, obesity, diabetes mellitus, nutritional status, microbial colonization, coexisting infections, or antibiotics used before surgery belong to the most important factors dependent on the patient [3–5]. The preparation of the patient for surgery, the duration of surgery, the type of surgery or surgical style (surgeon's competence and technique), the amount of blood lost and transfused, the covering of wounds, hand hygiene and disinfection belong to factors dependent on the hospital, comprising preoperative, intraoperative, and postoperative procedures, exhibit a high degree of preventability regarding the development of SSI [6, 7].

SSIs make up roughly 20% of all hospital-acquired infections [8, 9], and about 5% of patients undergoing surgery develop the SSI that requires an average additional 7 days of hospitalization [10]. Regarding the cervical spine surgery,

✉ Vera Spatenkova
vera.spatenkova@nemlib.cz

Extended author information available on the last page of the article

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the pooled incidence of SSI reaches in average 3.4% as showed in one recent meta-analysis study [11], but could reach more favorable values when anterior approach is used (0.1% to 1.6% found in [12–14]).

The preventive multimodal wound control protocol comprises multiple preventive measures that reduce the incidence of SSI [15, 16]. It is an important set of procedures or techniques focusing on the preoperative, intraoperative, and postoperative period, comprising proper surgical hand preparation (before and after all care procedures), patient skin preparation, antibiotic prophylaxis, operating theatre organization, and discipline [6, 7, 17, 18].

An important part of the preventive multimodal wound control protocol is optimal antibiotic prophylaxis focusing on effective dosing and its timing before and during operation, with no continuation after surgery. It is important to mention that excessive or inappropriate use of antibiotics also belongs to well-known problems worsening an epidemiological status due to multidrug-resistant bacteria [19, 20]. For all these reasons, quality control management for the prevention of SSIs must be carefully elaborated and maintained.

The aim of this study was to analyze the incidence of SSIs of elective cervical spine surgery under the guidance of our multimodal preventive wound control protocol. This study is a continuation of our previous single-center study that analyzed the incidence of SSIs after lumbar and thoracic surgery [21].

Materials and methods

Study setting

This study was carried at the Neurocenter of the Regional Hospital with 900 beds, analyzing patients who underwent spine surgery over a 6-year period from 2005 to 2010. It examined 797 patients who met the entry criteria: (1) cervical spine surgery performed by neurosurgeons, (2) elective operations, and (3) postoperative care in our eight-bed adult neurointensive care unit (NICU). The exclusion criteria involved: (1) acute surgery, (2) antibiotics used after surgery, and (3) the postoperative period commenced in the standard neurosurgery bed ward. The demographic data of this population, spine diagnoses, and duration of stay in the NICU, along with the values of body mass index (BMI), are shown in Table 1.

Study design

The monocentric observational cohort study was carried out after the approval of the Regional Hospital Ethics Committee for Multicentric Clinical Trials. The data processed were obtained from the prospective database of preventive multimodal nosocomial infection control protocol. The database is maintained since 2001 and contains prospective data related to all parameters collected with respect to monitored nosocomial infections in our NICU as well as other parameters related to patients' health status.

Table 1 Descriptive statistics of demographic and clinical data of patients with cervical spine surgery

Parameter ($N = 797$)	Unit	%	Mean	Standard deviation	Median	Lower quartile (25%)	Upper quartile (75%)
Age	Year		51.58	11.74	51.00	44.00	58.00
Female	pts	43.91% (350)					
Male	pts	56.09% (447)					
Weight	kg		79.20	15.96	78.00	68.00	90.00
Body mass index (BMI)			26.87	4.41	26,40	23.85	29.60
Spine diagnoses							
Degenerative disease	pts	85.19% (679)					
Trauma	pts	11.04% (88)					
Tumor	pts	3.76% (30)					
Stay							
Neurointensive care unit	Day		1.19	0.96	1.00	1.00	1.00
Standard neurosurgery ward	Day		4.39	4.60	3.00	3.00	4.00
Total hospital stay	Day		6.90	12.11	4.00	4.00	5.00
Diabetes mellitus	pts	9.66% (77)					
Ulcer prophylaxis	pts	14.30% (114)					
Omeprazole	pts	12.67% (101)					

N—number of patients, BMI—Body mass index

The following clinical parameters were observed: (1) spine diagnosis; (2) parameters associated with operations—surgery approach and technique, number of vertebrae involved in surgery, reoperations, duration of surgery, use of instrumented fixation; (3) presence of drainage, mechanical ventilation, catheters (artery, central venous), diuresis; (4) administration of corticoids (methylprednisolone, hydrocortisone), transfusions, ulcer prophylaxis, and diabetes mellitus; (5) postoperative care—during the NICU stay evaluated by the Therapeutic Intervention Scoring System (TISS).

The actual physical status and clinical health condition of our patients were evaluated using the American Society of Anesthesiologists (ASA) score and the Acute Physiology and Chronic Health Evaluation (APACHE) II score (supplemented by levels of C-reactive protein (CRP) and BMI values, see Table 2).

Multimodal preventive wound control protocol

A crucial part of a preventive multimodal wound control protocol is an optimal antibiotic prophylaxis that focuses on effective dosing and its timing before and during operation, with no continuation after the operation. Cefazolin was the first antibiotic choice, with Clindamycin administered in the case of allergy to beta-lactam antibiotics. Cefazolin was administered 30–60 min before surgery (that is, before the incision, 2 g if body mass was less than 100 kg, otherwise 3 g), and readministered if the surgery lasted more than 4 h, or if the blood loss was greater than 1.5 L. The dose of Clindamycin used was 600 mg, 60 min before surgery, and repeated if surgery was longer than 6 h. (For body weight above 100 kg the dose was 900 mg.)

The hygienic regime consisted of the following measures: (1) hand hygiene before and after all care procedures; (2) surgical face masks, surgical caps, sterile surgical gowns, sterile insertion of systems during invasive procedures; (3) disinfection with soap before entering the operating theatre; (4) rules and procedures for drainage and tubes: single-use products, closed systems only, emphasis on the shortest duration of procedures, minimization of disconnections of used port systems, regular as well as irregular replacements according to the vendor instructions and recommendations; (5) full wound coverage and keeping wounds dry and sterile; (6) full isolation of patients with infections (use of separated patient boxes, enhanced barrier precautions, treating and disposing health-care waste as contaminated, etc.); (7) daily cleaning and disinfecting of surfaces including beds, monitors and other equipment around the bed, door handles and floors.

Surgical site infections

Surgical site infections were defined according to (1) clinical symptoms, (2) bacterial pathogens, (3) imaging methods, (4) biochemical and hematological laboratory tests, according to the CDC guidelines for SSI [1]. Surgical site infections were followed up for 1 year after surgery.

Statistical analysis

Statistical analysis was performed using STATISTICA 13.2 software (TIBCO Software Inc., Palo Alto, CA, USA). We evaluated mainly the parameters of descriptive statistics, comprising medians, means, standard deviations (SD), frequencies, percentage, and quartiles of evaluated variables.

Results

Of the total of 797 patients included in the study, 2 patients had SSI (0.25% of all enrolled individuals, all patients began their postoperative period in the NICU). There was 1 patient with deep surgical site infection and 1 patient with organ/space osteomyelitis. Both patients had preceding wound complications: wound dehiscence in the case of deep surgical site infection and liquorrhea in the case of osteomyelitis. The deep surgical site infection occurred 15 days after the posterior approach to the cervical spine and was caused by Enterobacter cloacae. The osteomyelitis was diagnosed 7 days after the anterior cervical spine surgery and was caused by Staphylococcus aureus. Both patients had diabetes mellitus. The incidence of SSI of the anterior surgical approach was thus 0.14% (one of 706 patients) and of the posterior approach 1.4% (one of 68 patients).

There were 17 patients (2.13%) who had noninfectious wound complications and therefore were not classified as SSI according to the CDC guidelines [1]. Table 3 shows in detail the type of wound complications. They comprised mostly temporary secretion (7 patients), dehiscence (4 patients, 2 cases with dehiscence only, 1 case with dehiscence and secretion, 1 case with dehiscence and hematoma), liquorrhea (2 patients), hematoma (1 patient), and edema (3 patients).

Discussion

The incidence of surgical site infections (SSI) is an indicator of operation care quality and represents an unavoidable risk in any surgery [22]. It reaches 2–11% in all surgical interventions according to the data referred in [23]. It depends both on factors related to the patient characteristics and on factors related to procedures performed on the patient before,

Table 2 Characteristics of cervical spine operations

Parameter ($N = 797$)	Unit	%	Mean	Standard deviation	Median	Lower quartile (25%)	Upper quartile (75%)
Number of vertebrae							
1	pts	56.71% (452)					
2	pts	34.25% (273)					
3	pts	6.02% (48)					
ASA score 1–2		81.68% (651)					
Reoperation	pts	5.14% (41)					
Time of operation	Minutes		103.72	59.17	90.00	70.00	120.00
Operation approach							
Anterior	pts	88.58% (706)					
Posterior	pts	8.53% (68)					
Instrumented fixation	pts	92.22% (735)					
Drainage	pts	96.24% (767)					
Redon	pts	95.61% (762)					
One drainage	pts	85.82% (684)					
Transfusions	pts	1.13% (9)					
Blood loss	ml		160.61	327.40	50.00	50.00	100.00
Hemoglobin	g/l		130.00	16.86	131.00	121.00	142.00
Corticoids	pts	8.66% (69)					
Methylprednisolone	pts	1.38% (11)					
Hydrocortisone	pts	5.65% (45)					
Antibiotic prophylaxis	pts	98.49% (785)					
1-dose operation 1 V	pts	89.71% (715)					
2-dose operation 2 V	pts	5.77% (46)					
Cefazolin	pts	86.83% (692)					
Clindamycin	pts	10.92% (87)					
Postoperative period							
TISS—NICU admission			57.72	0.76	58.00	58.00	58.00
APACHE II—NICU admission			7.22	3.05	7.00	5.00	9.00
CRP day OP			6.32	14.60	2.00	1.00	5.00
CRP 1 day after OP			23.76	23.02	16.00	8.00	31.00
Mechanical ventilation	pts	1.13% (9)					
Artery catheters	pts	5.14% (41)					
	Day		2.59	2.60	1.00	1.00	3.00
Central venous catheter	pts	2.01% (16)					
	Day		5.94	4.82	5.50	2.00	9.00
Urine catheter	pts	49.69% (396)					
	Day		1.32	1.56	1.00	1.00	1.00

ASA—American Society of Anesthesiologists, NICU—neurointensive care unit, TISS—Therapeutic Intervention Scoring System, APACHE—Acute Physiology and Chronic Health Evaluation, CRP—C-reactive protein, OP—operation

during, and after surgery. The incidence of SSI related to spine surgery [24] ranges from 0.7 to 11.9% according to the following data [25–27]. It is often considered an indicator of the sanitary, hygienic, and microbiological regime of a given surgical department and ICU [28], but is also dependent, as mentioned, on the extend and the type of surgery. For example, the Surgical Invasiveness Index (SII)—a composite score comprising the number of vertebrae levels involved, the type of surgery performed at each level, the amount of blood loss, and the duration of surgery—belongs to proven SSI predictors. (An increase in the SII score is associated with a higher incidence of SSI, [29].)

Complications inflicted by SSI should be avoided, although this is not an easy task to achieve. A very important prerequisite in reducing SSIs is a well-managed multimodal preventive protocol focusing on factors that are preventable,

Table 3 Wound complications

Parameter ($N = 797$)	Unit	Number	%
Wound complications	pts	17	2.13
Secretion	pts	7	0.88
Dehiscence	pts	2	0.25
Dehiscence with secretion	pts	1	0.13
Dehiscence with hematoma	pts	1	0.13
Hematoma	pts	1	0.13
Edema	pts	3	0.38
Liquorrhea	pts	2	0.25
Surgical site infections	pts	2	0.25
Deep surgical site infections	pts	1	0.125
Organ/Space—Osteomyelitis	pts	1	0.125

including sanitary, hygienic, and microbiological measures, minimizing the contamination of surfaces and wounds with endogenous or hospital pathogens [6]. Established procedural methods in the preoperative and perioperative period confirm a high degree of preventability of SSI [3].

A good clinical outcome of the patient is certainly a primary target; however, there are also implications and concerns for a whole health system. Among them, there are prolonged hospitalizations, increased demands for additional care, increased financial costs, adverse effects on epidemiological status, and antibiotic policy due to the necessity of extensive use of antibiotics. The most demanding aspect of any protocol is not to introduce it, but to adhere to it and keep it working effectively. That must be carried out implicitly by the entire team, focusing equally responsibly and thoroughly on the preoperative, operative, and postoperative period.

In our study, we focused on both anterior and posterior cervical spine operations. We included a relatively large group of patients, summing up 797 individuals who over a six-year period met the study entry criteria (elective cervical spine surgery and the beginning of the postoperative period in NICU). Our results are based on collected data respecting the definition of SSI according to Horan et al. [22] and the CDC SSI guidelines [1]. Over the period of one year following the operation, we observed only 2 cases of SSI, just 0.25% altogether. The reason for such a low incidence of SSI can be seen in the dominance of cases treated for degenerative diseases (85.19%) and possibly in the high prevalence of the anterior approach (88.58%), which has a significantly lower incidence of SSI [30], which corresponds with the SSI incidence in our cohort of patients (0.14% with anterior vs. 1.4% with posterior, or 0.25% comprising both approaches). In one study, analyzing 452 cases, even no SSI was found associated with the anterior spine approach, regardless of the vertebrae level operated [31]. The anterior approach also implies a smaller blood loss (mean 160.61 ± 327.40). This corresponds to the fact that the transfusion was only given to 9 patients, which could have resulted in fewer SSI. (Blood loss and subsequent transfusion are considered to increase the risk of SSI [32], although some works consider blood transfusion to be only a confounding variable that correlates with the duration of surgery [4].) Furthermore, most of our patients had low ASA scores (1–2 in 81.68% of patients), which could also have caused sampling bias toward a healthier population exhibiting fewer SSIs. Among other factors that could be responsible for the low SSI incidence of our patients is the low average age (51.58 years), the relatively low BMI (26.87), and the short total stay in the hospital (6.9 days, 1.19 in the NICU + 4.39 in the standard neurosurgery ward). Furthermore, the fact that all our patients underwent elective surgery may play a role in our low incidence of SSI, since the patient's preparation for surgery, as well as the surgical procedure, could have been performed more cautiously and deliberately compared to acute surgery. Thus, all the facts mentioned could contribute to the observed low incidence of SSI. This can be compared to other studies focusing on cervical surgery referring the incidence of SSI 1.6% ([12]—both approaches combined analyzing 39,893 patients), 1.2% ([13]—a systematic review calculating a pooled incidence analyzing 965,867 patients with anterior approach), or 0.1% (found in [14] analyzing 1015 patients after anterior approach). A certain role in the low incidence of cervical spine SSIs could be attributed to the fact that wounds from spine surgery are located further from the sites or predilected sources of enteral bacterial flora (anus and perineal regions, contaminating surgical wounds due to the patients excretion and related sanitary procedures), an assumption that can partially be supported by a significantly higher SSI incidence of lumbar and thoracic surgery performed at our neurosurgery center (adhering to the same wound prevention protocol, however, with an incidence of SSI reaching 8% [21]).

Risk factors that increase the incidence of SSI include noninfectious wound complications, such as secretion, dehiscence, or liquorrhea. Our wound complications can be seen in Table 3. It is vital to pay special attention to every uninfected wound complication, as they are prone to become infected in a very short time interval. The antibiotic policy, including dosing and scheduling, also plays a very important role in the management of SSIs. With the protocol that is followed properly, it seems that it is not necessary to administer antibiotics in the postoperative period. In our study, only 16 (2.01%) patients received prolonged antibiotic prophylaxis, mainly due to common accidents during surgery (e.g., ruptured gloves). There is a rule in our neurocenter imposing monitoring of all patients after the cervical spine surgery in the NICU to minimize complications until patients are fully stabilized. So, all patients in our study begin their postoperative period in the NICU (this postoperative period

was short and lasted 1.19 ± 0.96 days), followed by a stay in the standard neurosurgery bed ward (4.39 ± 4.6 days). That could have reduced the incidence of SSI with surgical wounds carefully monitored and meticulously treated there. However, NICUs, or in general ICUs, are also known to have a generally higher risk of acquiring multiresistant bacterial pathogens [33] compared to staying in the standard surgical ward. Thus, in general, the resulting SSI incidence could be affected in any direction, depending on the actual epidemiological status of a given ICU (especially worrying are the pathogens known as MRSA—Methicillin-resistant Staphylococcus aureus, and extended spectrum β-lactamase (ESBL) producing enterobacteria). At our NICU, the risk of multidrug-resistant bacteria and nosocomial infection was shown to be low [34]. A routine surgical technique performed by our team that focuses on a narrow spectrum of surgery types could also be taken into account to explain the lower incidence of SSI. In our NICU, we pay special attention to comply with the rules of our protocol, keeping the wounds dry and completely covered, and trying not to prolong the antibiotic prophylaxis unnecessarily. Since one of our main goals was to evaluate the validity of our multimodal preventive wound control protocol, having only 2 SSIs from 797 patients (0.25%) indicates that our protocol is effective and contributes significantly to the minimalization of SSIs.

Our study has several limitations. Low and favorable ASA (81.68% of patients had ASA scores 1–2) can be considered as one of them, resulting in the lack of SSI data on the incidence of SSI in patients with higher, possibly more frequent ASA scores. A higher ASA score directly increases the incidence of wound complications and implies a prolonged stay in hospital, thus contributing additionally to the higher incidence of SSI. We also did not assign our patients to subgroups of smokers and nonsmokers, the state of nutrition on SIS incidence was also not studied in detail, as well as we were not able to extract other risk factors of SIS from our data. The main reason behind that is that in the presented study we had only 2 cases of SSI from 797 patients enrolled in the study, which prevented meaningful comparison of these two incommensurable groups of patients (case group comprising 2 patients vs. 795 patients that would make a control group), and hindered any reasonable comparative analysis of SSI risk factors within our group of patients. Since this is an observational, single-center study, we were also not able (for ethical as well as operational reasons) to compare two groups of patients, one under our current multimodal preventive wound protocol, with another one adhering to a different protocol. We are fully aware that the low incidence of SSI in this study is also partially a consequence of other factors that are not fully related to the parameters of our preventive wound protocol, factors already discussed in previous paragraphs, related primarily to the characteristics of the population involved in this study.

Conclusions

The incidence of surgical site infection can be kept considerably low in the cervical spine surgery once the proper multimodal preventive wound control protocol is introduced and maintained. (In our case, the incidence of SSI after anterior surgical approach was 0.14%, after posterior approach 1.4%, and for both approaches 0.25%.) These values pertain to specific group of patients observed in our hospital who underwent the elective cervical surgery, had an average age close to 51 years, a low ASA score (1–2 in 81.68% of patients), and an indication for surgery due to degenerative disorders (85.19%).

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Authors' contributions V.S. conceived and designed the study, acquired, interpreted the data, and drafted the manuscript; O.B. performed the statistical analysis and interpreted the data; Z.M. acquired the data; P.S. interpreted the data; J.H. acquired and interpreted the data, drafted the manuscript; E.K. interpreted the data and drafted the manuscript, M.H. interpreted the data. All authors read and approved the final manuscript.

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Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request. The data are not publicly available because they contain information that could compromise participant privacy. Incidence of surgical site infections after cervical spine surgery: Results of a single-center cohort study adhering to multimodal preventive wound control protocol.

Declarations

Conflict of interest The authors declare that they have no conflicts of interest.

Ethical approval Approval from the Institutional review board of our hospital was obtained from the hospital Ethics Committees for Multicentric Clinical Trials (ref. EK27). All procedures performed in the study were in accordance with the ethical standards and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. All participants gave written informed consent prior to all measurements and agreed upon publication.

Consent for publication All authors agree for publication.

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Authors and Affiliations

Vera Spatenkova[1,2,3,4] · Ondrej Bradac[5] · Zuzana Mareckova[6] · Petr Suchomel[4,6] · Jan Hradil[6] · Eduard Kuriscak[3] · Milada Halacova[7]

Ondrej Bradac
ondrej.bradac2@fnmotol.cz

Zuzana Mareckova
zuzana.mareckova@nemlib.cz

Petr Suchomel
petr.suchomel@nemlib.cz

Jan Hradil
jan.hradil@nemlib.cz

Eduard Kuriscak
ekuri@lf1.cuni.cz

Milada Halacova
milada.halacova@homolka.cz

[1] Neurocenter, Neurointensive Care Unit, Regional Hospital, Husova 357/10, 46063 Liberec, Czech Republic

[2] Department of Anaesthesia and Intensive Care, 3 Medical Faculty, Charles University, Srobarova 50, 100 34 Prague, Czech Republic

[3] Institute of Physiology, First Medical Faculty, Charles University in Prague, Albertov 5, 12800 Prague 2, Czech Republic

[4] Faculty of Health Studies, Technical University of Liberec, Studentská 1402/2, 461 17 Liberec 1, Czech Republic

[5] Department of Neurosurgery, 2nd Faculty of Medicine, Charles University in Prague and Motol University Hospital, V Úvalu 84/1, 150 06 Prague, Czech Republic

[6] Neurocenter, Department of Neurosurgery, Regional Hospital, Husova 357/10, 46063 Liberec, Czech Republic

[7] Department of Clinical Pharmacology, Na Homolce Hospital, Roentgenova 37/2, 150 30 Prague 5, Czech Republic

3.3.3. Individualized perioperative management in transoral spine surgery: a single-center cohort study evaluating surgical wound complications and wound infections. BMC Anesthesiology. 2022

Poslední čtvrtá habilitační práce se zabývala infekcemi v místě chirurgického výkonu u operací krční páteře transorálním přístupem. Z hlediska výskytu infekčních komplikací se jedná o operace páteře s vysokým rizikem [112], které vyžadují individualizovaný perioperační přístup. Tyto operace jsou současně chirurgicky náročné, často vyžadují i další operaci zadním přístupem, a v neposlední řadě je nutné zmínit, že se jedná o vzácné operace krční páteře. Cílem tohoto výzkumu bylo zhodnocení individualizovaných preventivních perioperačních postupů z pohledu intenzivní péče na vznik SSI, jako je zajištění dýchacích cest pomocí předoperační tracheostomie, pooperační umělá plicní ventilace nebo zavedení nazogastrické sondy k zajištění výživy.

Za přednost tohoto výzkumu lze považovat analýzu našeho dlouhodobého vývoje, která ukázala, že dodržovaný individualizovaný preventivní perioperační přístup nepředstavuje riziko SSI u těchto transorálních operacích krční páteře, a to ani u výkonu provedených z důvodu primárního zánětlivého onemocnění. Význam této práce spočívá v potvrzení rizikového zadního přístupu při operacích páteře i při srovnání s transorálním přístupem. Dalším důležitým přínosem této práce je zjištění, že neinfekční komplikace v operační ráně nemusí u transorálního přístupu vést k SSI, a že tedy kvalita péče o operační ránu je významný faktorem eliminace SSI a doporučené nastavení preventivních postupů vykazuje vysoký stupeň preventability SSI. Tento výzkum vedl na našem pracovišti k dalšímu zpřísnění protokolu péče o operační ránu.

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Individualized perioperative management in transoral spine surgery: a single-center cohort study evaluating surgical wound complications and wound infections

Vera Spatenkova[1,2,3,4*], David Sila[5], Milada Halacova[6], Jan Hradil[7], Zdenek Krejzar[5,8] and Eduard Kuriscak[2]

Abstract

Background: Transoral spine surgery is specific due to both its surgical approach and the spectrum of diseases it targets. Patients with high age and elevated clinical frailty scores are often involved, and there are reports of increased risks of surgical site infection (SSI) due to extended exposures requiring maxilotomy or mandibulotomy. Our case series describes surgical wound complications under the meticulous application of individualized perioperative multimodal management.

Methods: Our primary outcome was the occurrence of SSI and the secondary outcome was the occurrence of other noninfectious wound complications evaluated in 22 adult patients who consecutively underwent the transoral spine surgery from 2001 to 2018 (trauma – C2, cervical nonunion: 6 patients, 27%; tumor: 4 patients, 18%; osteomyelitis: 6 patients, 27%; other non-traumatic cases: 6 patients, 27%). Structuralized data comprising parameters related to nosocomial infections after spine surgery were continuously processed and put into specialized database of preventive multimodal nosocomial infection control protocol that was used as a main source of analyzed parameters. The mean age of studied cohort was 54.9 ± 15.5 years, with 68% males, mean body mass index (BMI) 24.9 ± 5.22, and the mean clinical frailty score was 2.59 ± 1.07. There were 7 patients (32%) who only had the transoral approach and 15 patients (68%) having this approach followed by additional posterior approach. We observed SSI from all wound complications for up to one year after surgery.

Results: There were 4 (18%) superficial wound complications from transoral approach, but none of them were infected. We had 2 patients (13%) with deep wound infections after subsequent posterior approach, but only one (4.5%) was classified as SSI.

Conclusions: We describe the wound complications and the incidence of SSI in a series of 22 patients after the transoral surgery. Considering the average values of the clinical frailty score reaching 2.59, American Society of Anesthesiologists score of 2.73, and the BMI of 26.87, the transoral spine surgery did not seem to be a considerable risk for SSI in the analyzed cohort, provided preventive perioperative multimodal management is properly individualized and followed.

Keywords: Surgical site infection, Transoral, Surgery, Frailty, Wound complications, Antibiotic prophylaxis, Skull base

*Correspondence: vera.spatenkova@nemlib.cz
[1] Neurocenter, Neurointensive Care Unit, Regional Hospital, Husova 357/10, 46063 Liberec, Czech Republic
Full list of author information is available at the end of the article

Introduction

Transoral (TO) spine surgery is specific due to both its surgical approach and the spectrum of diseases it targets [1, 2]. Patients with high age and elevated clinical frailty scores are often involved and there are reports of increased risk of surgical site infection (SSI) mainly due to perioperative considerations, technical aspects pertaining the TO approach, prolonged surgery and more complex techniques involving maxilotomy or mandibulotomy [3]. The perioperative stress is often increased by a necessity for an additional surgery—a stabilization via posterior approach. The preventive perioperative multimodal management has an important role in the reduction of adverse events of SSI. A careful and individualized perioperative strategy is necessary and represents an indicator of operation care quality.

The transoral approach was introduced by Kanavel [4] in 1917 as a novel approach to reach the upper cervical vertebrae (C1-C2). Surgical site infections represent an unavoidable risk in any surgery, but in the TO spine surgery, the risk of SSI is increased due to the food intake during the postoperative period and the possibility of perioperative wound contamination. The preventive multimodal wound control protocol relies on a hygienic regime in the operative and postoperative periods and assumes a correct antibiotic prophylaxis [5, 6]. An inappropriate (often excessive) use of antibiotics worsens the epidemiological status and leads to the rise of multidrug resistant bacteria.

In this study we focused on the description of:

1) the important aspects and parameters of individualized perioperative management (duration of mechanical ventilation, use of endotracheal and tracheostomy tubes, nasogastric tubes, arterial and venous catheters, type of nutrition and drug prophylaxis)
2) the risks of the TO approach for odontoid osteomyelitis compared to non-infectious pathologies (including the SSI risks for subsequent posterior approach)
3) the recurrent osteomyelitis after surgery
4) the influence of the extent of TO surgery on the SSI
5) the time interval between the TO surgery and the additional surgery via posterior approach.

The aim of this case series study is the characterization of surgical wound complications. We focused on the primary outcome which was the evaluation of the incidence of SSI after the transoral surgery that adheres meticulously to a modern perioperative preventive multimodal wound control protocol individualized according to the patient status. The secondary outcome we were interested in was the occurrence of noninfectious surgical wound complications (dehiscence, hematoma, secretion, liquorrhea, metalwork prominence, etc.).

Materials and methods

Data source and data collection

The prospective database of preventive multimodal nosocomial infection control protocol of the Neurointensive Care Unit, belonging to the Regional Hospital Neurocenter—one of the country's spinal surgery centers—is maintained since 2001. It contains prospective data related to all parameters collected with respect to monitored nosocomial infections in our NICU, and other parameters related to patients' health status. This study analyses a series of 22 patients who underwent the TO surgery consecutively from 2001 to 2018, with no patients excluded from this study. Our TO surgery patients have been recruited from all over the republic. We classified SSI according to the location of infection into superficial (involving skin and subcutaneous tissue), deep (deep soft tissue as fascial and muscle layers), and organ/space (part of the body deeper than the fascial/muscle layers that is opened or manipulated during the operative procedure). The patient status was classified mainly by intensive and emergency medicine scores and indexes, namely, the American Society of Anesthesiologists (ASA) score, the Acute Physiology and Chronic Health Evaluation (APACHE) score, the Therapeutic Intervention Scoring System (TISS), and by the three types of patient frailty scoring systems (Frailty index, Frailty index-11 and Clinical frailty score) related to postoperative morbidity and mortality.

The demographic data, history of diseases and spine diagnosis are listed in Table 1.

The type of operation approach, duration of surgery, instrumented fixation, blood loss, transfusions, drainage, ASA score, are seen in Table 2. Postoperative neurocritical care procedures and related details (mechanical ventilation, endotracheal tube, tracheostomy tube, arterial, central and urine catheters, gastrointestinal tube, body temperature, use of corticoids, ulcer prophylaxis, nutrition), associated health complications, TISS and APACHE II scores, are all described in Table 3. Particular numbers of patients and durations in days listed in Table 3 show our individualized approach regarding the postoperative care, demonstrating our decisions respecting individual conditions of our patients before the surgery, the type of surgery, and their conditions after the surgery. We individually considered these conditions and made decisions regarding:1) the use of mechanical ventilation using endotracheal tube or tracheostomy tube, 2) urine catheters, 3) peroral vs. enteral (nasogastric

Table 1 Demographic and clinical data of the patients

Parameter (*N* = 22)	Unit	%	Minimum	Maximum	Mean	Standard deviation	Median
Age	year		23	77	54.9	15.5	60
Female	pts	31% (7)					
Male	pts	68% (15)					
Weight	kg		41	105	72.0	17.1	73.0
Body Mass Index			23.8	29.6	26.8	4.4	26,4
Spine diagnoses							
Trauma	pts	27% (6)					
Non-union of the dens axis fracture	pts	5					
Tumor	pts	18% (4)					
Chondroma	pts	2					
Metastasis	pts	1					
Other non-traumatic	pts	27% (6)					
Rheumatoid arthritis	pts	2					
Osteomyelitis	pts	27% (6)					
Localization							
C 1–2	pts	68% (15)					
C 2	pts	27% (6)					
C 2–4	pts	4% (1)					
Coronary artery disease	pts	4% (1)					
Arterial hypertension	pts	54% (12)					
Bronchial asthma	pts	9% (2)					
COPD	pts	4% (1)					
Chronic renal failure	pts	9% (2)					
Hepatopathy	pts	13% (3)					
Gastroduodenal ulcer	pts	9% (2)					
Diabetes Mellitus	pts	13% (3)					
Smoking	pts	18% (4)					
Ethylism	pts	13% (3)					
Frailty index			0	5	1.27	1.35	1
Frailty index 11			0	0.45	0.11	0.12	0.09
Clinical frailty score			1	5	2.59	1.07	3
Stay in the ICU			0	35	8.41	7.74	6.50
Total our hospital stay			1	73	23.45	16.99	18.50

N Number, *C* Cervical, *COPD* Chronic Obstructive Pulmonary Disease, *ICU* Intensive Care Unit

tube) vs. parenteral nutrition (further parameters are listed in Table 3 and also in Table 4 which describes the use of antibiotics). Laboratory data (preoperative and postoperative blood and biochemical parameters like hemoglobin, hematocrit, leukocytes, glycemia, albumin, proteins, lactate, C-reactive protein) are in Table 5.

In the study we also included parameters related to an overall health status of the patient represented by the Frailty Index [7], Frailty Index 11 [8] and Clinical Frailty score [7] as seen in Table 1.

Study design

The approval to process the data from our preventive multimodal nosocomial infection control protocol database was issued by the Hospital Ethics Committee (ref. number of approval EK27). All participants gave written informed consent prior to all measurements and agreed with publication. All methods were performed in accordance with the relevant guidelines and regulations.

As mentioned, the TO surgery cohort consisted of a series of 22 patients, with the mandibular or maxillary split indicated in 6 (27%) patients. In the subgroup of

Table 2 Characteristics of the operations

Parameter	Unit	N	%	Minimum	Maximum	Mean	Standard deviation	Median
ASA score				1	4	2.73	0.69	3
Day of hospitalization	day	22		1	21	6.86	5.75	4.5
Time of operation	minutes			25	1320	339	288	325
Biopsy before	pts		13% (3)					
Transoral operation	pts	22	31% (7)					
Transoral and posterior	pts		68% (15)					
Consecutive	pts		14					
Biopsy only	pts		0% (0)					
Odontoid resection	pts	22	72% (16)					
Extensive approach	pts		27% (6)					
Posterior approach	pts							
Graft only	pts		6% (1)					
C1-C2 Magerl, Gallie	pts	15	26% (4)					
C1-C2 Harms	pts		20% (3)					
Occipito-cervial fusion	pts		46% (7)					
Graft								
Without	pts		13% (2)					
Bone substitute	pts	15	6% (1)					
Autologous free	pts		33% (5)					
Autologous fix	pts		46% (7)					
Drainage Posterior	pts		100% (15)					
Suction drainage	pts		14					
	number	15		1	2	1.50	0.50	1.50
	day			2	3	2.14	0.35	2.00
Gravity drainage	pts		2					
Blood loss	ml	22		50	4000	1305	1333	800
Transfusions	pts		31% (7)					

N Number, *ASA* American Society of Anesthesiologists

15 probands, the TO approach was supplemented by a subsequent dorsal fixation operation – the posterior surgery route.

Patients were divided into two subgroups according to the extent of transoral resection:

1) subgroup of simple transoral odontoid resection and
2) subgroup of more extensive approach with the split of either maxilla or mandibula.

The data concerning the posterior approach (concerning 15 patients) fell into 4 subgroups:

1) dorsal interlaminar grafting only
2) transarticular C2-C1 Magerl fixation supplemented by interlaminar Gallie fusion
3) C1-C2 Harms fixation and fusion
4) occipito-cervial fusion

Every preventive multimodal wound control protocol comprises of a correct antibiotic prophylaxis with an emphasis on dosage and timing of administration before and during the operation. Cefazolin was our first choice of antibiotic, with Clindamycin administered in case of allergy to beta-lactam antibiotics. Cefazolin was administered 30–60 min before surgery (namely before the incision, 2 g if the body mass was less than 100 kg, otherwise 3 g), and re-administered, if the surgery lasted longer than 4 h, or if the blood loss was bigger than 1.5 L. The dose of Clindamycin was 600 mg, administered 60 min before surgery, and repeated if it was longer than 6 h (for body weight above 100 kg the dose was 900 mg). The prolonged use of antibiotics after the operation was reduced as much as possible. We adhered the antiseptic regime of surgery approach, wound care, single-use products, closed systems, the minimum duration of surgery, minimal and only necessary disconnection of used port systems.

Table 3 Characteristics of the postoperative period

Parameter (*N* = 22)	Unit	%	Minimum	Maximum	Mean	Standard deviation	Median
Admission TISS			52	58	55.10	1.57	55
Admission APACHE II			2	15	8.90	3.69	9.50
Mechanical ventilation	pts	45% (10)					
Time	day		1	17	3.90	4.78	1.50
Endotracheal tube	pts	13% (3)					
Time	day		1	1			
Tracheostomy tube	pts	54% (12)					
Time	day		2	85	13.58	22.58	4.00
Artery catheter	pts	59% (13)					
Time	day		1	12	4.50	2.87	4.50
Radialis	pts	12					
Central venous catheter	pts	31% (7)					
Time	day		2	19	9.17	5.27	7.50
Subclavia	pts	5					
Femoralis	pts	2					
Urine catheter	pts	90% (20)					
	day		1	33	8.05	7.98	4.00
Nasogastric tube	pts	81% (17)					
	day		1	15	5.06	3.24	5.00
Body temperature (max)			33	39.5	37.3	2.05	38.00
Complications							
Delirium	pts	9% (2)					
Respiratory	pts	9% (2)					
Hemodynamics	pts	40% (9)					
Acute kidney injury	pts	18% (4)					
Dysphagia	pts	27% (6)					
Enteral nutrition	pts	68% (15)					
	day		2	11	4.46	2.44	4.00
Parenteral nutrition	pts	22% (5)					
	day		1	28	9.40	9.77	7.00
Insulin	pts	40% (9)					
Ulcer prophylaxis	pts	72% (16)					
Corticoids	pts	68% (15)					
Dexamethasone	pts	3					
Methylprednisolone	pts	6					
Hydrocortisone	pts	5					

Parameters in the table represent numbers of patients or days that demonstrate either the size of patient subgroups or the duration of complications in days, as well as our decisions respecting the individual approach to our patients during the perioperative period

N Number, *TISS* Therapeutic Intervention Scoring System, *APACHE* Acute Physiology and Chronic Health Evaluation

Surgical site infections were defined according to 1) clinical symptoms, 2) bacterial pathogens, 3) imaging methods, 4) biochemical and hematological laboratory tests. SSI were followed and evaluated up to one year after the surgery.

Statistical analysis

The statistical analysis was done in Microsoft Excel. We evaluated parameters of descriptive statistics. We calculated minima, maxima, medians, means, standard deviations (SD), frequencies and percentages of evaluated variables.

Results

Regarding the presented cohort of patients undergoing the TO surgery, there were 4 (18%) patients with transoral superficial wound complications (2 patients with tumor, one with traumatic etiology, one with

Table 4 Antibiotic prophylaxis in the non-infection transoral surgery

Parameter (*N* = 16)	Unit	%
Antibiotic prophylaxis	pts	72% (16)
Operation doses	pts	25% (4)
Day 1	pts	6% (1)
Day 2	pts	6% (1)
Day more than 2	pts	62% (10)
Antibiotic 1	pts	37% (6)
Antibiotic 2	pts	56% (9)
Antibiotic 3	pts	6% (1)
Cefazolin	pts	75% (12)
Amoxicillin clavulanate	pts	56% (9)
Clindamycin	pts	6% (1)

N Number

non-traumatic etiology). However, none of those patients had infection of the wound. The noninfectious complications from the TO approach were the dehiscences of the pharyngeal mucosa that were solved with a conservative treatment and concerned 3 nonsmoker patients with BMI 21.8, 24.2, and 26.2. They had the nasogastric tube for 5, 8, 14 days, and started to eat orally once the dehiscence was cured. Noninfectious wound complication of the fourth patient was the metalwork prominence which caused serious dysphagia and was solved surgically by reoperation on 27th day (that patient was cachectic, ethylic and smoker, with BMI 13.9). None of those four patients had pathological cultivation, all had tracheostomia, all received Amoxicilin clavulanat as profylaxis, and three of them were on mechanical ventilation.

Two deep wound infections were registered after the posterior approach surgery. The first wound infection developed in the 69-year-old lady with the frailty index score 3, after the TO and subsequent posterior spine surgery lasting 440 min altogether, with a blood loss of 1000 ml (it was performed due to nonunion of the fracture of axis vertebra). This infection occurred 34 days after the surgery, so it was classified as SSI according to the SSI guidelines [9]. It was caused by Bacteroides species and Peptostreptococcus species according to microbiological testing. This deep infection was found in a surgical wound with healed skin suture underneath which a subcutaneous palpable pus collection (containing approx. 30 ml of thick smelling pus) was found and punctured. That patient had a higher risk of SSI because she had tonsillitis with fevers reaching 39 °C, which was treated with Amoxicilin clavulanat antibiotics before this SSI was found.

The second deep wound infection was observed in a 63-year-old man with the frailty index score 3, after the TO and subsequent posterior spine surgery lasting 1320 min both, with a blood loss reaching 4000 ml. This operation was performed due to a C2 chordoma extending into surrounding tissues, and the infection appeared 6 months after the surgery as a purulent fistula and recurrence of a chondroma. Pathogens were identified as Staphylococcus aureus and Escherichia coli. However, that infection was not classified as SSI according to the CDC guidelines [9] since it had not appeared within a 90-day period after surgery. Thus, the overall incidence of SSI after the TO approach reached 4.5% (in one of 22 patients) in our cohort.

Table 1 shows the spectrum of spine diagnoses involved in this study, frailty scores and indexes, patient comorbidities and demographics. In Table 2 are seen details about performed surgery, blood loss and transfusions. The postoperative care details that are reflecting our individualized postoperative approach that is taking into account preoperative as well as postoperative conditions and complications influencing our decision regarding the appropriate approach for each patient (duration of mechanical ventilation, use of the endotracheal tube,

Table 5 Laboratory examination

Parameter	Unit	Reference range	Before operation mean ± SD	After operation mean ± SD	
Haemoglobin	g/l	135–175	129.45 ± 18.35	93.05 ± 22.09	The lowest value
Hematocrit		0.4–0.5	0.38 ± 0.06	0.28 ± 0.07	The lowest value
Leukocytes	10^9/l	4–10	7.37 ± 2.84	17.31 ± 4.79	The highest value
Albumin	g/l	35–52	34.54 ± 5.47	26.42 ± 7.19	The lowest value
Protein	g/l	66–87	70.50 ± 4.70	43.91 ± 26.00	The lowest value
C-reactive protein	mg/l	0–5	11.54 ± 14.55	94.44 ± 75.20	The highest value
Glycemia	mmol/l	4.1–5.6	6.04 ± 2.02	10.6 ± 3.44	The highest value
Lactate	mmol/l	0.36–0.75		2.76 ± 1.51	On admission ICU
				3.10 ± 2.03	The highest value

SD Standard Deviation, *ICU* Intensive Care Unit

tracheostomy tube, nasogastric tube, type of nutrition and pharmacotherapy, etc.), are listed in Table 3. Detailed information on antibiotic prophylaxis are seen in Table 4. Table 5 contains information on blood examinations before and after surgery.

Discussion

Surgery via transoral approach is considered to have an inherently higher risk of SSI and a higher number of complications during the postoperative period. This is mainly attributed to a specific surgical route through the oral cavity and less familiar anatomy associated with it [10, 11]. These appear to be factors limiting a wider adoption of this technique, however, regarding the incidence of SSI, there is some data indicating that the TO approach does not necessarily increase it when compared to the posterior approach, at least concerning the 30-day follow-up period after surgery [12].

The gradual renaissance of the TO approach is linked not only with newer operative technologies (e.g., anterior fixation via the TO approach [13] or robot-assisted TO [14]), but also with a deeper understanding of preventive and therapeutical measures. These include a standardized preventive multimodal wound control protocol that is concentrating on the preoperative, perioperative and postoperative phases, being properly individualized to respect the health status of the patient, an approach that is playing a pivotal role in the success of the treatment. The incidence of SSI is thus considered a significant quality indicator of surgery and individualized perioperative care.

In our prospective database of preventive multimodal nosocomial infection control protocol, we analyzed 22 patients who underwent the TO surgery during the reference period from 2001 to 2018. Both infectious and non-infectious pathologies were included in the study. Our results show one SSI developed after the TO surgery. There were 4 superficial wound complications (3 mechanical dehiscences of the pharyngeal mucosa and 1 metalwork prominence) after the TO approach, however, with no pathological cultivation, and this complication was not detected in patients with osteomyelitis surprisingly.

Our data shows 4.5% incidence of SSI after the TO surgery, which means that the SSI developed in just one patient whose spine was fixed anyway with the consecutive posterior surgery—a value comparable with other monocentric studies focusing on the SSI incidence after TO surgery. In a study by Yin et al. [3], the incidence reached 3.5% (172 patients), and in [12] it was 1.79% (56 patients).

TO surgery often requires subsequent posterior spine stabilization. This can be done in a single session (in case there is a significant loss of spinal stability after TO surgery), or it can be postponed and performed separately under more favorable conditions. The combination of TO surgery and consecutive fixation with posterior approach was performed in 15 patients, with 14 patients undergoing single-stage surgery, leading to longer total operation times (mean 339 min). Although the duration of surgery is known to be a significant factor increasing the incidence of SSI [15, 16], it is very likely that such surgery durations did not increase the incidence of SSI in our patients.

Having just one SSI in our cohort of 22 patients also reflects the indication criteria (see Table 1), and a deliberate selection of patients elected for TO surgery in our hospital. A proper selection of patients, based on the complex conciliar discussion that is considering possible prognosis and outcomes, and the meticulous preoperative preparation, are of the utmost importance for a long-term success of TO surgery. Taking into account the extent and the duration of this type of surgery, only patients with responsibly chosen TO indication and in good health conditions will have acceptable postoperative complications and low mortality rate. In the reported cohort, there were no highly polymorbid patients: coronary artery disease—1 patient, COPD—1 patient, chronic renal failure—2 patients, diabetes mellitus—3 patients. 12 patients had arterial hypertension and there was no substantial obesity (mean BMI 26.87). The ASA score (mean 2.73) and the clinical frailty score (mean 2.59) reflect our deliberate selection of patients undergoing the extensive TO surgery. We included frailty scores (see Table 1) because many clinicians think this scale has a good predicting value and commonly outperforms other measures of comorbidity and risk of death—or outcomes of serious health conditions, including complications from surgery and corresponding postoperative mortality and morbidity [7, 8].

Standardized wound care is an irreplaceable part of the multimodal wound control protocol. This includes the individualized preoperative assessment of risks and the intended extent of surgery. To the most important steps belong the individualized decisions about transoral/transnasal intubation versus tracheostomy (12 patients, 55%), which is influencing the incidence of SSI, favoring the latter as more advantageous in this regard. Also, the form of nutrition after the TO surgery must be responsibly assessed since the nasogastric line is placed near surgery wounds and could increase the incidence of SSI during the postoperative period. We used enteral nutrition in 15 patients (68%), and only 5 patients required parenteral nutrition (5 patients, 23% patients).

The wound care is rather atypical in patients undergoing the TO surgery and consists of proper preoperative

preparation, meticulous technique of closure and proper postoperative regime. Any contact between the wound and the tubes (endotracheal, nasogastric, etc.) should be avoided. If this is not feasible, changes must be made in the position of the tubes to prevent decubitus. We observed 3 cases of superficial pharyngeal dehiscence with negative bacteriological cultivations. These defects often involve only part of the suture and tend to heal quickly by epithelization in the absence of bacterial superinfection. There was only one SSI despite the 6 cases of osteomyelitis and the use of corticoids in 15 patients (68%).

The most common postoperative complication seen was a hemodynamic instability requiring vasopressors (9 patients, 41%). The mean lactate level after surgery was 2.76 mmol/L, with a maximum value reaching 3.1 mmol/L.

One of the most important parts of the protocol is a proper antibiotic policy. The unique nature of TO surgery prevented us from adhering to a protocol used in general spine surgery (one dose preoperatively and intraoperative administration only – that was applied only in 4 cases). There were 2 patients receiving antibiotics for up to 48 h postoperatively and 10 patients (63%) who received another dose of antibiotics. Prolonged prophylaxis was required in 3 cases of superficial dehiscence, but some of reported patients (namely those with osteomyelitis) required prolonged antibiotic therapy. The cefazolin was used as a first-choice prophylactic antibiotic (12 patients, 75%), followed by Amoxicillin clavulanate (9 patients, 56%).

Our study has several limitations. Despite a 17-year span, we only had 22 patients undergoing the TO surgery in our neurocenter. Moreover, our population sample had a low number of polymorbid and obese patients, low frailty score and low number of smokers.

However, the study is monocentric, analyzing our own cases of relatively rare TO surgery, known to be much less frequent compared to other types of spine surgery.

Conclusions

We analyzed wound complications and the incidence of SSI in a series of 22 patients undergoing the transoral surgery. We report the ASA, APACHE and TISS scores as well as the three frailty measures correlating with the patient health status. Having only one SSI, and taking into account evaluated patient score levels, we would like to conclude that the transoral spine surgery did not seem to be a considerable risk for SSI in our cohort, assuming an individualized perioperative multimodal preventive management and adequate indication criteria for TO surgery are met.

Abbreviations

APACHE: Acute Physiology and Chronic Health Evaluation; ASA: American Society of Anesthesiologists; C: Cervical; COPD: Chronic Obstructive Pulmonary Disease; ICU: Intensive Care Unit; N: Number; NICU: Neuro-Intensive Care Unit; SSI: Surgical Site Infection; SD: Standard Deviation; TISS: Therapeutic Intervention Scoring System; TO: Trans-Oral.

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Authors' contributions

V.S. conceived and designed the study, acquired and interpreted the data, performed statistics and drafted the manuscript; D.S. acquired the data; M.H. interpreted the data, J.H. acquired and interpreted the data and drafted the manuscript; Z.K. interpreted the data; E.K. interpreted the data and drafted the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due due to the anonymity of the participants but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved (ref. number EK27) by the Hospital Ethics Committee for Multicentric Clinical Trials belonging to the Regional Hospital Liberec. All participants gave written informed consent prior to all measurements and agreed upon publication. All methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no conflicts of interest.

Author details

[1]Neurocenter, Neurointensive Care Unit, Regional Hospital, Husova 357/10, 46063 Liberec, Czech Republic. [2]First Medical Faculty, Institute of Physiology, Charles University, Prague, Czech Republic. [3]Department of Anaesthesia and Intensive Care Medicine Third Medical Faculty, Charles University, Prague, Czech Republic. [4]Faculty of Health Studies, Technical University of Liberec, Liberec, Czech Republic. [5]Anaesthesia and Intensive Care Department, Regional Hospital Liberec, Liberec, Czech Republic. [6]Department of Clinical Pharmacology, Na Homolce Hospital, Prague, Czech Republic. [7]Neurocenter, Department of Neurosurgery, Regional Hospital Liberec, Liberec, Czech Republic. [8]Department of Neurology First Medical Faculty, Charles University, Prague, Czech Republic.

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Publisher's Note

4. Seznam zkratek

ACS	American College of Surgeons
APACHE	Acute Physiology and Chronic Health Evaluation
ASA	American Society of Anesthesiologists
BSI	Blood stream infection
CAUTI	Catheter-associated urinary tract infection
CLABSI	Central line-associated blood stream infection
CNS	Centrální nervový systém
CPE	Carbapenemase producing Enterobacteriaceae
CRBSI	Catheter-related blood stream infection
ECDC	European Centre for Disease Prevention and Control
ESBL	Extended spectrum β-lactamases
GCS	Glasgow Coma Scale
GOS	Glasgow Outcome Scale
HAI	Healthcare-associated Infection
HAP	Healthcare-associated pneumonia
JIP	Jednotka intenzivní péče
MDR	Multidrug resistant
MRSA	Methicilin-rezistentní *Staphylococcus aureus*
NAP	Národní antibiotický program
NJ	Neurointenzivní jednotka
Protokol	Preventivní multimodální protokol nozokomiálních infekcí
SCIE	Science Citation Index Expanded
SSI	Surgical Site Infection

TISS	Therapeutic Intervention Scoring System
VAP	Ventilator-associated pneumonia
VAT	Ventilator-associated tracheobronchitis
VRE	Vancomycin-resistantní Enterococcus
WHO	World Health Organization
WOS	Web of Science

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6. Komentář

Habilitační práce s názvem Infekce spojené se zdravotní péčí u onemocnění mozku a páteře je předkládána jako komentovaný soubor čtyř publikací, které všechny hodnotily efektivitu Preventivního multimodálního protokolu nozokomiálních infekcí zavedeného v roce 2001 na neurointenzivní jednotce Neurocentra v Krajské nemocnici Liberec.

První habilitační práce představuje nejrozsáhlejší část výzkumu. Prospektivní klinická studie hodnotila u 3646 pacientů s primárním onemocněním mozku účinnost nastaveného preventivního multimodálního protokolu, a to v dlouhém časovém rozmezí od 2001 do 2010. Studie prokázala, že takhle nastavený preventivní program vede k výraznému poklesu incidence HAI, v našem případě se jednalo o snížení z 9,1 % na 4,7 % pacientů. Současně výzkum potvrdil velmi nízkou incidenci MDR bakterií, ESBL mělo 1,9 % pacientů a MRSA 1,5 % pacientů. Tyto výsledky ukazují, že aktivní přístup v nastavení a udržování komplexního preventivního multimodálního protokolu má zásadní význam na výskyt HAI a MDR bakterií v neurointenzivní péči.

Další tři habilitační práce se zaměřovaly na SSI u pacientů po operacích páteře, kteří měli pooperační péči na NJ. Tyto prospektivní studie se zabývaly páteří v celém jejím rozsahu od krční po lumbální oblast. První zpracovaná studie se věnovala plánovaným operacím hrudní a bederní páteře, přičemž bylo prokázáno, že se jedná o jednu z nejrizikovějších oblastí páteře z hlediska výskytu SSI a že mezi signifikantní prediktory jejich vzniku patří neinfekční komplikace v operační ráně a teplé roční období. Součástí první práce bylo i sledování racionalizace profylaktické antibiotické politiky, kvůli čemuž došlo již v letech 2006 až 2010 u velkého počtu pacientů (95,8 %) k realizaci podání antibiotika jen před a během operačního výkonu. Navazující

výzkumná práce hodnotila SSI po plánovaných operacích krční páteře. Výsledky této práce potvrdily, že se jedná z hlediska výskytu SSI o nejméně rizikovou oblast (0,25 % pacientů), přičemž zadní operační přístup je rizikovější než přední. Poslední oblast výzkumu byla zaměřena na transorální operace krční páteře. Z pohledu SSI se jedná o operace s vysokým rizikem, které vyžadují individualizovaný perioperační přístup. Přínos této práce spočívá v zjištění, že neinfekční komplikace v operační ráně nemusí u transorálního přístupu vést k SSI a že zadní operační přístup je rizikovější i v porovnání s transorálním přístupem. Důvodem rozdělení výzkumu do třech samostatných celků je rozdílné riziko vzniku SSI v jednotlivých úsecích páteře, a naším cílem bylo identifikování nejrizikovější oblasti. Výzkum SSI po operacích páteře potvrdil, že tyto komplikace mají vysoký stupeň preventability, že k jejich eliminaci je nezbytný aktivní přístup preventivních postupů a že nejvyšší prioritu zaujímá kvalita péče o operační ránu. Celý výzkum o SSI po operacích páteře se stal v roce 2023 pilířem pro obhájení prestižního evropského certifikátu Centra excelence ve spinální chirurgii od evropské společnosti Spine Society of Europe v oblasti kontroly infekcí.

Předkládaná habilitační práce prezentuje náš dlouhodobý výzkum v oblasti prevence HAI v neurointenzivní péči. Naše výsledky prokázaly, že se našemu týmu podařilo účinně nastavit a realizovat komplexní preventivní multimodální program, který byl postavený na všech zásadních principech, na hygienických a protiepidemických opatřeních, na racionální antibiotické politice, na výskytu MDR bakterií a na kontrole infekcí. Nejvyšší přínos naší práce spočívá v získání výsledků prokazujících, že HAI v neurointenzivní péči jsou preventabiliní onemocnění, kterým lze účinně předcházet.

7. Commentary

The habilitation thesis titled Healthcare Associated Infections in Brain and Spine Diseases is presented as a commentary on four publications which evaluated the effectiveness of the Preventive Multimodal Nosocomial Infection Protocol implemented in 2001 at the Neurointensive Care Unit of the Neurocentre at the Regional Hospital Liberec.

The first habilitation thesis constitutes the most extensive part of the research. A prospective clinical trial evaluated the efficacy of a set preventive multimodal protocol in 3646 patients with primary brain disease, over a lengthy time span from 2001 to 2010. The study showed that this prevention programme led to a significant decrease in the incidence of HAI, in our case from 9.1 % to 4.7 % of patients. At the same time, the research confirmed a very low incidence of MDR bacteria, with 1.9 % of patients having ESBL and 1.5 % of patients having MRSA. These results show that a proactive approach in setting and maintaining a comprehensive preventive multimodal protocol is of major importance for the incidence of HAI and MDR bacteria in neurointensive care.

The remaining three habilitation papers focused on SSIs in patients following spine surgery who had postoperative care in the Neurointensive Care Unit. These prospective studies covered the spine in its entirety from the cervical to the lumbar region. The first of these studies looked at elective thoracic and lumbar spine surgery, and it was shown that this is one of the riskiest areas of spine surgery in terms of SSIs, and that significant predictors of SSIs include non-infectious complications in the surgical wound and warm seasons. Part of this first work included monitoring the rationalization of prophylactic antibiotic policy, which already led to the implementation of antibiotic

administration only before and during surgery in a large number of patients (95.8 %) between 2006 and 2010. A follow-up study evaluated SSIs after elective cervical spine surgery. The results of this work confirmed that this is the lowest risk area in terms of SSI incidence (0.25 % of patients), with the posterior surgical approach being riskier than the anterior approach. The last area of research focused on transoral cervical spine surgery. From an SSI perspective, these are high-risk operations that require an individualized perioperative approach. The main contribution of this work is the finding that non-infectious complications in the surgical wound may not lead to SSI in the transoral approach and that the posterior surgical approach is also riskier compared to the transoral approach. The reason for dividing the study into three separate units is the different risk of SSI in different sections of the spine, and our aim was to identify the area at highest risk. Research on SSIs after spine surgery has confirmed that these complications have a high degree of preventability, that a proactive approach of preventive procedures is essential to eliminate them, and that the quality of surgical wound care is of the highest priority. The entire SSI post-spine surgery research became a pillar in defending the prestigious European Centre of Excellence in Spine Surgery certification from the Spine Society of Europe in infection control in 2023.

The present habilitation thesis presents our long-term research in the field of HAI prevention in neurointensive care. Our results demonstrate that our team was able to effectively set up and implement a comprehensive multimodal prevention programme based on all essential principles, hygiene and anti-epidemic measures, a rational antibiotic policy, and MDR bacteria prevalence and infection control. The most important achievement of our work is in obtaining results demonstrating that HAIs in neurointensive care are preventable diseases that can be effectively prevented.