

STREPTOCOCCUS PNEUMONIAE: YUQISHI, KOLONIZATSIYASI VA INVAZIYASI MEXANIZMLARI

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Annotatsiya. Ushbu maqolada *Streptococcus pneumoniae* ning yuqishi, nasofarinksda kolonizatsiyalanishi va invaziv kasallik rivojlanish mexanizmlari tahlil qilindi. Pnevmonokokkning inson yuqori nafas yo'llarida opportunistik patogen sifatida tutgan o'rni hamda uning pnevmoniya, otit, sepsis va meningit kabi kasalliklar etiologiyasidagi ahamiyati yoritildi. Tadqiqot davomida kapsula polisaxaridi, pneumolizin, yuzaki adgezinlar va bakteriyaning mezbon immun tizimi, xususan komplement tizimi bilan o'zaro ta'siri baholandi. Shuningdek, virusli ko-infeksiyalarning, ayniqsa gripp infeksiyasining, pnevmonokokk transmissiyasi va invaziv salohiyatini kuchaytiruvchi omil sifatidagi roli ko'rsatildi. Olingan xulosalar pnevmonokokk patogenezini chuqurroq tushunish hamda samarali profilaktika va vaksina strategiyalarini ishlab chiqishda muhim ilmiy asos bo'lib xizmat qiladi.

Kalit so'zlar: *Streptococcus pneumoniae*, kolonizatsiya, transmissiya, pneumolizin, kapsula polisaxaridi, invaziv pnevmonokokk kasalligi, immunitet, komplement tizimi

STREPTOCOCCUS PNEUMONIAE: МЕХАНИЗМЫ ПЕРЕДАЧИ, КОЛОНИЗАЦИИ И ИНВАЗИИ

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Аннотация. В данной статье проанализированы механизмы передачи *Streptococcus pneumoniae*, его колонизация в носоглотке и развитие инвазивных форм заболевания. Освещена роль пневмококка как оппортунистического патогена верхних дыхательных путей человека, а также его значение в этиологии пневмонии, отита, сепсиса и менингита. В ходе исследования

оценено значение капсульного полисахарида, пневмолизина, поверхностных адгезинов и взаимодействия бактерии с иммунной системой хозяина, в частности с системой комплемента. Показана роль вирусных ко-инфекций, особенно гриппа, как факторов, усиливающих передачу и инвазивный потенциал пневмококка. Полученные выводы имеют важное значение для более глубокого понимания патогенеза пневмококковой инфекции и разработки эффективных профилактических и вакцинных стратегий.

Ключевые слова: *Streptococcus pneumoniae*, колонизация, трансмиссия, пневмолизин, капсульный полисахарид, инвазивная пневмококковая инфекция, иммунитет, система комплемента

STREPTOCOCCUS PNEUMONIAE: MECHANISMS OF TRANSMISSION, COLONIZATION, AND INVASION

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Abstract. This article analyzes the mechanisms of transmission, nasopharyngeal colonization, and the development of invasive disease caused by *Streptococcus pneumoniae*. The role of pneumococcus as an opportunistic pathogen of the human upper respiratory tract and its significance in the etiology of pneumonia, otitis media, sepsis, and meningitis are highlighted. The study evaluates the contribution of capsular polysaccharide, pneumolysin, surface adhesins, and the interaction of the bacterium with the host immune system, particularly the complement system. In addition, the role of viral co-infections, especially influenza, as factors enhancing pneumococcal transmission and invasive potential is demonstrated. The findings provide an important scientific basis for a deeper understanding of pneumococcal pathogenesis and for the development of effective preventive and vaccination strategies.

Keywords: *Streptococcus pneumoniae*, colonization, transmission, pneumolysin, capsular polysaccharide, invasive pneumococcal disease, immunity, complement system

Kirish. *Streptococcus pneumoniae* (pnevkokk) inson organizmi bilan yaqin evolyutsion munosabatga ega bo'lgan gram-musbat, kapsulali bakteriya bo'lib, asosan yuqori nafas yo'llari, xususan, nasofarinks shilliq qavatida kommensal sifatida yashaydi [1,3]. Ko'plab hollarda pnevmokokk tashuvchiligi klinik belgilar bilan

namoyon bo'lmaydi, biroq u epidemiologik jihatdan muhim bo'lib, infeksiya tarqalishining asosiy manbai hisoblanadi [2]. Tadqiqotlar natijalariga ko'ra, bolalarning 27–65% ida, kattalarning esa 10% dan kam qismida pnevmokokk tashuvchiligi aniqlanadi, bu esa yosh omili kolonizatsiya intensivligida muhim rol o'ynashini ko'rsatadi [1,2].

Pnevmokokkning hayot sikli shartli ravishda uch asosiy bosqichga bo'linadi: birinchi bosqich — mezbondan mezbonga yuqish, ikkinchi bosqich — nasofarinksda kolonizatsiya va uzoq muddat saqlanib turish, uchinchi bosqich esa bakteriyaning epitelial to'siqlardan o'tib, quyi nafas yo'llari, qon oqimi yoki markaziy asab tizimiga tarqalishi natijasida invaziv kasalliklarning rivojlanishi [3,18]. Ushbu bosqichlar bir-biri bilan chambarchas bog'liq bo'lib, pnevmokokkning patogen salohiyatini belgilaydi.

Pnevmokokkning eng muhim virulentlik omili kapsula polisaxaridi (CPS) hisoblanadi. Kapsula bakteriyani mezbon immun tizimining asosiy komponentlaridan biri bo'lgan komplement tizimi va fagotsitozdan himoya qiladi [19,22], shu orqali uning yashovchanligini va invaziv salohiyatini oshiradi. Bundan tashqari, pneumolizin toksini epitelial hujayralarga zarar yetkazib, kuchli yallig'lanish javobini chaqiradi va bakteriyaning to'qimalar bo'ylab tarqalishiga qulay sharoit yaratadi [16,29]. Virusli infeksiyalar, ayniqsa gripp, pnevmokokk patogenezida muhim qo'zg'atuvchi omil sifatida e'tirof etiladi. Virus ta'sirida nafas yo'llari epiteliasida retseptorlar ekspressiyasi kuchayadi, shilliq qavat bar'yeri zaiflashadi va bakterial yuklama oshadi [8–14]. Natijada pnevmokokkning kolonizatsiya samaradorligi hamda transmissiya ehtimoli sezilarli darajada kuchayadi, bu esa invaziv pnevmokokk kasalliklari rivojlanish xavfini oshiradi.

Maqsad. Pnevmonokokkning yuqish mexanizmlarini, kolonizatsiya jarayonini, immun tizimidan qochish strategiyalarini, invaziv kasallik rivojlanish bosqichlarini zamonaviy ilmiy ma'lumotlar asosida tizimli tahlil qilish.

Material va metodlar. Mazkur maqola ikkilamchi ma'lumotlarga asoslangan tahliliy tadqiqot bo'lib, unda *Streptococcus pneumoniae* ning yuqishi, kolonizatsiyasi va invaziv salohiyatiga oid zamonaviy ilmiy ma'lumotlar tizimli ravishda umumlashtirildi. Tadqiqot jarayonida xalqaro miqyosda nufuzli ilmiy jurnallarda chop etilgan mikrobiologik, immunologik va eksperimental tadqiqotlar natijalari tahlil qilindi. Ma'lumotlar manbasi sifatida molekulyar biologiya usullari orqali olingan natijalar, laboratoriya hayvonlari ishtirokida o'tkazilgan eksperimental modellar (shu jumladan, yangi tug'ilgan sichqon va ferret modellarida bajarilgan kolonizatsiya hamda transmissiya tadqiqotlari), shuningdek, insonlarda nazorat ostida olib borilgan kolonizatsiya tajribalari va klinik kuzatuvlar ma'lumotlaridan foydalanildi. Olingan ma'lumotlar pnevmokokkning virulentlik omillari, mezbon immun javobi bilan o'zaro ta'siri hamda tashqi va ichki omillarning bakterial transmissiyaga ta'sirini baholash maqsadida qiyosiy va integrativ yondashuv asosida

tahlil qilindi. Ushbu yondashuv pnevmokokk patogenezining asosiy bosqichlarini kompleks yoritish imkonini berdi.

Natijalar. O‘tkazilgan tahlil natijalari *Streptococcus pneumoniae* ning yuqishi, kolonizatsiyasi, immun tizimidan qochish mexanizmlari hamda invaziv kasallik rivojlanishida bir qator muhim omillar ishtirok etishini ko‘rsatdi [1–3,18].

Pnevmokokkning yuqishi asosan yaqin va davomli kontakt orqali amalga oshishi aniqlandi [6,7]. Nafas yo‘llaridan ajralib chiqadigan shilliq sekretiya bakterianing tashqi muhitga chiqarilishida asosiy rol o‘ynaydi [7]. Virusli ko-infeksiyalar, xususan, gripp viruslari bilan birga kechgan holatlarda burun shilliq qavatida sekretiya miqdori oshib, bakterial “shedding” jarayoni kuchayadi [8–11]. Bunda pneumolizin toksinining yallig‘lanishni kuchaytiruvchi ta’siri transmissiyani yanada faollashtiradi [16]. Shu bilan birga, kapsula polisaxaridining qalinligi pnevmokokkning shilliq qavatdan ajralib chiqishini osonlashtirib, yuqish ehtimolini oshirishi kuzatildi [19,22].

Kolonizatsiya bosqichida pnevmokokkning nasofarinks epiteliasiga mahkam yopishishi uning barqaror saqlanib qolishida hal qiluvchi ahamiyatga ega ekanligi aniqlangan [1,3]. Bu jarayonda PavA, PavB, CbpA, NanA va BgaA kabi yuzaki oqsillar epitelial hujayralar bilan o‘zaro ta’sirga kirishib, bakterianing shilliq qavat yuzasida mustahkam joylashishini ta’minlaydi [15,17]. Bundan tashqari, hujayra membranasidagi fosforilxolin (ChoP) bilan trombosit faollashtiruvchi omil retseptori (PAFR) o‘rtasidagi o‘zaro ta’sir pnevmokokkning epitelial hujayralarga kirib borishini osonlashtiradi [15]. Kolonizatsiya samaradorligi shuningdek, nasofarinks mikrobiotasi bilan bo‘ladigan raqobatga bog‘liq bo‘lib, bakteriosinlar ishlab chiqarilishi pnevmokokkning ustunligini ta’minlovchi muhim omil sifatida namoyon bo‘ldi [20,21].

Immun tizimidan qochish mexanizmlari tahlili pnevmokokkning mezbon himoya tizimini samarali ravishda chetlab o‘tishini ko‘rsatdi [18]. Kapsula polisaxaridi komplement tizimining muhim komponenti bo‘lgan C3b ning bakteriya yuzasiga birikishini cheklab, opsonizatsiya va fagotsitozni susaytiradi [19,22]. Shu bilan birga, PspA va CbpA oqsillari komplement faolligini inhibe qilib, bakterianing immun hujayralar tomonidan tanilib yo‘q qilinishidan saqlanishiga yordam beradi [17,19]. Mukozal immunitet darajasida esa IgA1 proteazaning ta’siri natijasida sekretor immunoglobulin A parchalanib, shilliq qavatdagi himoya mexanizmlari zaiflashadi [26]. Pneumolizin pora hosil qiluvchi xususiyati orqali hujayra membranalari shikastlab, sitokinlar ishlab chiqarilishini kuchaytiradi va yallig‘lanish javobini rag‘batlantiradi [16,29].

Invaziya bosqichida kuchli yallig‘lanish jarayoni va epitelial to‘siqlarning shikastlanishi pnevmokokkning nasofarinksdan quyi nafas yo‘llari, qon oqimi hamda boshqa steril to‘qimalarga o‘tishiga imkon yaratishi aniqlangan [25,26]. Ayniqsa,

yosh bolalar va keksalarda immun tizimining yetilmaganligi yoki zaiflashganligi invaziv pnevmokokk kasalliklarining ko‘proq uchrashiga olib keladi [1,25]. Ushbu guruhlarda bakteriyaning tarqalishi tezlashib, og‘ir klinik holatlar rivojlanish xavfi ortadi [25].

Muhokama. Olingan natijalar *Streptococcus pneumoniae* ning patogenezini mezbondan organizm bilan murakkab o‘zaro ta’sirga asoslanganligini ko‘rsatadi [1,3,18]. Pnevmonokokk uchun eng muhim bosqich nasofarinksda kolonizatsiya bo‘lib, aynan shu jarayon bakteriyaning saqlanib qolishi va mezbondan mezbonga yuqishini ta’minlaydi [1,3]. Invaziv kasalliklar esa ko‘pincha ushbu jarayonlarning ikkilamchi natijasi sifatida rivojlanadi [18]. Yuqish jarayonida yaqin kontakt va shilliq sekretsionining ahamiyati yuqori bo‘lib, virusli ko-infeksiyalar, ayniqsa gripp, yallig‘lanishni kuchaytirish orqali bakterial yuklamani va transmissiya ehtimolini oshiradi [6–11]. Pneumolizinning proyallig‘lanish ta’siri ushbu jarayonni yanada faollashtiradi [16,29]. Kolonizatsiya bosqichida pnevmokokkning epiteliya yopishishi hal qiluvchi rol o‘ynaydi [3]. Yuzaki adgezinlar va ChoP–PAFR o‘zaro ta’siri bakteriyaning shilliq qavatda mustahkam joylashishiga yordam beradi, mikrobiota bilan raqobat esa kolonizatsiya muvaffaqiyatini belgilovchi muhim omil hisoblanadi [15,17,20,21].

Immun tizimidan qochish mexanizmlari pnevmokokkning yashovchanligini oshiradi [18]. Kapsula polisaxaridi va yuzaki oqsillar komplemet tizimini susaytirib, opsonofagotsitozni cheklaydi, IgA1 proteaza esa mukozal immunitetni zaiflashtiradi [19,22,26]. Invaziya asosan kuchli yallig‘lanish va epiteliyal to‘siqlarning shikastlanishi fonida yuzaga kelib, yosh bolalar va keksalarda og‘ir kechish xavfi yuqori bo‘ladi [25]. Shu sababli pnevmokokk infeksiyalarini oldini olishda kolonizatsiya va transmissiyani cheklashga qaratilgan profilaktik yondashuvlar muhim ahamiyatga ega [24,27,28].

Xulosa. *Streptococcus pneumoniae* inson yuqori nafas yo‘llarida keng tarqalgan kolonizator bo‘lib, uning patogenligi asosan yuqish, kolonizatsiya va immun tizimidan qochish mexanizmlarining samarali ishlashi bilan belgilanadi [1,3,18]. Nasofarinksda kolonizatsiya pnevmokokk hayot siklining markaziy bosqichi hisoblanib, bakteriyaning saqlanib qolishi va tarqalishini ta’minlaydi [3].

Kapsula polisaxaridi, pneumolizin va yuzaki adgezinlar pnevmokokkning asosiy virulentlik omillari bo‘lib, ular orqali bakteriya mezbondan immun javobini chetlab o‘tadi va shilliq qavatda barqaror joylashadi [16,19,22]. Virusli respirator infeksiyalar, xususan gripp, yallig‘lanishni kuchaytirib, pnevmokokk transmissiyasi va invaziya xavfini oshiradi [8–14]. Invaziv pnevmokokk kasalliklari ko‘pincha immun himoyasi zaiflashgan guruhlarda, jumladan yosh bolalar va keksalarda rivojlanadi [25]. Shu bois pnevmokokk infeksiyalarining oldini olishda kolonizatsiyani cheklashga qaratilgan profilaktik choralar, ayniqsa vaksinalar va

мukoзал имунитетни mustahkamlovchi yondashuvlar muhim ahamiyatga ega [24,25,27–30].

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