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PREDNOSTI I NEDOSTACI RENDGENSKE DIJAGNOSTIKE ZA OBOLELE OD VELIKOG KAŠLJA

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SAŽETAK

Svetska zdravstvena organizacija opisuje veliki kašalj kao „izuzetno zaraznu bolest respiratornog trakta koju uzrokuje *Bordetella pertussis*“, mikroorganizam specifično patogen za ljude. Veliki kašalj pogađa sve uzraste, posebno decu, i jedan je od vodećih uzroka smrti kod dece mlađe od jedne godine. Inkubacija obično traje 7 do 10 dana, a klinička slika zavisi od uzrasta i vakcinalnog statusa. Dijagnoza velikog kašlja često predstavlja izazov zbog simptoma koji su slični onima kod drugih respiratornih infekcija. Kod odraslih obično bolest prolazi asimptomatski ili se javlja blaga simptomatska infekcija, posebno kod starijih koji su prethodno vakcinisani. Međutim, kod dece mlađe od 5 godina, posebno odojčadi, je teža klinička slika u vidu paroksizmalnog kašlja, koji može biti praćen karakterističnim vizingom ili inspiratornim hukom i izbacivanjem male količine lepljive sluzi, a može da dođe i do pojave dispneje, cijanoze i apneje. Komplikacija koja se najčešće javlja kod nevakcinisane dece je bronhopneumonija. U cilju dijagnostikovanja bolesti, pored specifične kliničke slike, najčešće se koristi bris ili aspirat nazofaringsa za PCR testiranje ili kultivaciju bakterije i krv za serološke analize. Rendgenski snimak pluća kod lica sa sumnjom na veliki kašalj može imati značajnu ulogu u proceni komplikacija i diferencijalnoj dijagnozi, a kod mlađih od četiri godine i za olakšavanje postavljanja dijagnoze. Međutim, nedostaci rendgenskog snimanja pluća su napadi kašlja prilikom snimanja, nemogućnost otkrivanja bolesti u ranom stadijumu, izlaganja pacijenta jonizujućem zračenju i greške u interpretaciji snimaka.

Ključne reči: dijagnoza, rendgen pluća, veliki kašalj, komplikacije, diferencijalna dijagnoza

Uvod

Pertusis, poznat i kao veliki kašalj ili „kašalj od 100 dana“, prvi put je opisan u pariskoj epidemiji 1578. Uzročnik, *Bordetella pertussis*, otkriven je 1908. godine, a prva vakcina je licencirana 1914. godine, ali bez rutinske upotrebe sve do 1949. godine (1). U našoj zemlji je od 1960. godine započeto sa sprovođenjem rutinske vakcinacije protiv pertusisa korpuskularnom vakcinom, a od 2015. godine acelularnom vakcinom. Bez mogućnosti vakcinacije, pertusis je bio glavni uzrok obolevanja i umiranja novorođenčadi (2).

Bordetella pertussis je gram negativan kokobacil koji se vezuje za cilijarne nastavke respiratornih epitelnih ćelija. Lokalne inflamatorne promene se javljaju u sluzokoži respiratornog trakta. Oslobađaju se toksini (pertusisni toksin, dermonekrotični toksin, adenilat ciklazni toksin i trahealni citotoksin) koji deluju lokalno i sistemski, iako sam uzročnik ne prodire potpuno u respiratorni trakt i gotovo nikada se ne nalazi u hemokulturi (3). Iako je veliki kašalj bolest za koju postoji vakcina, bolest se održava endemski u svim zemljama sveta, a epidemijski se javlja na svake dve do pet godina (3). Danas se ponovo susrećemo sa sve većim brojem obolelih. Nevakcinisani i nepravovremeno vakcinisani, kao i relativno kratko trajanje imuniteta posle vakcinacije, doprinose povećanju broja slučajeva velikog kašlja u populaciji (4).

Dijagnoza velikog kašlja često predstavlja izazov zbog simptoma koji su slični onima kod drugih respiratornih infekcija. Osim toga simptomi i znaci pertusisa se razlikuju u zavisnosti od

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ADVANTAGES AND DISADVANTAGES OF X-RAY DIAGNOSIS FOR WHOOPING COUGH PATIENTS

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SUMMARY

The World Health Organization describes whooping cough as "a highly contagious disease of the respiratory tract caused by *Bordetella pertussis*," a microorganism specifically pathogenic to humans. Whooping cough affects all ages, especially children, and is one of the leading causes of death in children under one year of age. Incubation usually lasts 7 to 10 days, and the clinical picture depends on age and vaccination status. Whooping cough is often a challenge because of symptoms that are similar to those of other respiratory infections. In adults, the disease is usually asymptomatic or mild symptomatic infection occurs, especially in the elderly who have been previously vaccinated. However, in children under 5 years of age, especially infants, the clinical picture is more severe. It is in the form of paroxysmal cough, which may be accompanied by characteristic wheezing or inspiratory whooping and vomiting or expelling a small amount of sticky mucus. Dyspnea, cyanosis and apnea can also occur, especially in infants. The most common complication in unvaccinated children is bronchopneumonia. In order to diagnose the disease, in addition to the specific clinical picture, a nasopharyngeal swab or aspirate is most often used for PCR testing or bacterial cultivation and blood for serological analyses. X-ray of the lungs in persons with suspicion of whooping cough can play a significant role in the assessment of complications and differential diagnosis, and in children under four years of age, also in establishing the diagnosis. However, during chest X-ray imaging, coughing attacks during imaging, inability to detect the disease in the early stages, exposure of the patient to ionizing radiation, and errors in the interpretation of images may occure.

Key words: diagnosis, lung X-ray, whooping cough, complications, differential diagnosis

Introduction

Pertussis, also known as whooping cough or “the cough of 100 days“, was first described in the Paris epidemic in 1578. The causative agent, *Bordetella pertussis*, was discovered in 1908 and the first vaccine was licensed in 1914, but it was not routinely used until 1949 (1). In our country, routine vaccination against pertussis began in 1960 with corpuscular vaccine, while the acellular vaccine has been used since 2015. Since there was no possibility of vaccination, pertussis was the main cause of infant morbidity and mortality (2).

Bordetella pertussis is a gram-negative coccobacillus that adheres to the ciliated respiratory epithelial cells. Local inflammatory changes occur in the mucosal lining of the respiratory tract. Released toxins (pertussis toxin, dermonecrotic toxin, adenylate cyclase toxin and tracheal cytotoxin) act locally and systemically, although the causative organism itself does not fully penetrate the respiratory tract and it is almost never found in blood culture (3). Although pertussis is a disease, for which there is a vaccine, the disease remains endemic in all countries of the world, and epidemics occur every two to five years (3). Today, we again encounter an increasing number of patients. Unvaccinated persons and persons that were not vaccinated in time, as well as the relatively short duration of immunity

uzrasta (5,6). Kod odraslih sa kašljem do osam nedelja dijagnoza pertusisa se postavlja na osnovu prisustva paroksizmalnog kašlja, koji se završava iskašljavanjem male količine lepljive sluzi. Takođe, može da se javikarakterističan inspiratorni huk ili vizing (engl. *wheezing*). Ukoliko odrasla osoba koja kašlje ima temperaturu ili ako nema paroksizmalan kašalj onda se ne može govoriti o velikom kašlju. Kod dece sa kašljem koji traje < 4 nedelje javlja se paroksizmalni kašalj, karakteristični vizing, kao i povraćanje posle kašlja, što ukazuje na veliki kašalj. Specifično je da su napadi kašlja (paroksizmi) češće noću. Oni su brzi, snažni i ponavljajući, traju 1-2 minuta, bez udisaja, a završavaju dugim visokotonskim, duboko uvučenim udahom (pisak/huk). Često može da dođe do apnoične epizode. Stanje se pogoršava kako bolest odmiče. Moguć je razvoj komplikacija bolesti što zavisi od uzrasta (češće kod dece), od vakcinalnog statusa obolelog, od brzine postavljanja dijagnoze i terapije. Bronhopneumonija je najčešća komplikacija, dok su konvulzije i encefalopatije znatno ređe.

Stoga, u cilju postavljanja dijagnoze, pored kliničkih simptoma i znakova, postoji nekoliko laboratorijskih metoda za potvrdu dijagnoze (kultura – specifičnost 100%, lančana reakcija polimeraze – PCR – 88-100%, serologija – 72-100%, testiranje oralne tečnosti – 91-99%) (6).

Najčešće se od pacijenata uzimaju nazofaringealni bris ili aspirat i/ili uzorak krvi. Kod svih lica sa kašljem koji traje do dve nedelje radi se kultura, do tri nedelje PCR, a od druge do osme nedelje, najduže do dvaneste nedelje, serološka analiza. Rendgen pluća pomaže u cilju otkrivanja komplikacija, najčešće pneumonije, ali promene nisu specifične za veliki kašalj (6). Zbog sve veće učestalosti respiratornih infekcija razmatra se uloga rendgena pluća za njihovo dijagnostikovanje, pa tako i za dijagnostikovanje pertusisa.

Cilj ovog preglednog rada je da analizira prednosti i nedostatke rendgenske dijagnostike kod obolelih od velikog kašlja.

Metode

U ovom preglednom radu pretražene su elektronske baze podataka *Google Scholar* napredne pretrage, Konzorcijuma biblioteka Srbije za objedinjenu nabavku – KoBSON i platforma *PubMed*. U pretrazi su korišćene sledeće ključne reči: rendgen pluća, dijagnoza, veliki kašalj, prednosti i nedostaci. Korišćene su publikacije objavljene u periodu od 2014. do 2024. godine, na srpskom ili engleskom jeziku. Rezultati studija sprovedenih na temu rendgenske dijagnostike u slučajevima velikog kašlja prikazani su u narativnom obliku.

Epidemiološke i kliničke karakteristike velikog kašlja

Svetska zdravstvena organizacija (SZO) opisuje veliki kašalj kao „izuzetno zaraznu bolest respiratornog trakta koju izaziva *Bordetella pertussis*", specijalno patogenimikroorganizam za ljude. Veliki kašalj pogađa sve uzraste, posebno decu i jedan je od vodećih uzroka smrti kod dece mlađe od jedne godine. Inkubacija obično traje 7 do 10 dana (od jedne do tri nedelje), a kliničke manifestacije su povezane sa uzrastom i vakcinalnim statusom (4). Kod dece se bolest karakteriše paroksizmalnim kašljem koji je praćen karakterističnim inspiratornim vizingom i povraćanjem nakon kašlja. Takođe, može da dođe do cijanoze, dispneje i apneje. Adolescenti i odrasli često imaju atipične simptome i mogu imati samo uporni kašalj. Ozbiljnost bolesti je obrnuto proporcionalna uzrastu pacijenta (7). Naime, pertusis ima predvidljiv tok kod nevakcinisane dece i može rezultirati kliničkim tokom praćenim komplikacijama. Prognoza je posebno loša tokom prve i druge godine života, kada je učestalost hospitalizacije i smrtnih ishoda najviša (0,2% u razvijenim i 4% u nerazvijenim zemljama) (8). Bolest može imati blag i atipičan tok kod vakcinisane dece, adolescenata i odraslih, zbog čega se retko otkriva kod ovih osoba. Naime, ovi pacijenti mogu biti značajan izvor infekcije za malu decu, posebno decu u prvoj godini života, kada imunološki sistem još uvek nije dovoljno razvijen (4). Nekoliko seroepidemioloških studija je pokazalo da je bolest veoma česta kod tinejdžera i odraslih (7,9), odnosno da su oni važni izvori infekcije za malu decu.

Infekcija pertusisom je pokazala imunomodulatorne efekte, sa nedavnim istraživanjima fokusiranim na ulogu adenilat ciklaznog toksina (CyaA) i proteinskih efektora sistema za sekreciju tipa III (TTSS) koji mogu uticati na patogenezu osnovnih hroničnih stanja/bolesti, posebno na hronične inflamatorne bolesti (10,11). Postoje dokazi da infekcija koju uzrokuje *Bordetella pertussis* može imati uticaj na astmatični napad (12), respiratorne bolesti (10) i druga atopijska stanja (13).

after vaccination contribute to the increase in the number of cases of pertussis in the population (4).

Diagnosis of pertussis is often challenging because of symptoms that are similar to the symptoms of other respiratory infections. In addition, the symptoms and signs of pertussis differ depending on age (5,6). In adults who cough for up to eight weeks, the diagnosis of pertussis is made based on the presence of paroxysmal cough, which ends with the coughing up of a small amount of sticky mucus. Also, the characteristic inspiratory whoop or wheezing can be heard. If an adult who coughs has a fever or if he does not have a paroxysmal cough, then it is not whooping cough. When cough lasts < 4 weeks in children, and when paroxysmal cough occurs, as well as wheezing and posttusive vomiting, it is whooping cough. It is specific that coughing fits (paroxysms) are more common at night. They are fast, forceful and repetitive, they last 1-2 minutes, without inhaled air, and they end in prolonged, high-pitched deeply indrawn breath (wheezing/whoop). An apneic episode can often occur. The condition worsens as the disease progresses. Complications are possible, and this depends on age (more common in children), on the vaccination status of the patient, on the timely diagnosis and therapy. Bronchopneumonia is the most common complication, while convulsions and encephalopathy are much less common.

Therefore, in order to establish the diagnosis, in addition to clinical symptoms and signs, there are several laboratory methods for confirming the diagnosis (culture – specificity 100%, polymerase chain reaction – PCR – 88-100%, serology – 72-100%, oral fluid testing – 91-99%) (6).

A nasopharyngeal swab or aspirate and/or blood sample are most often collected from patients. For all persons with a cough that lasts up to two weeks, a blood sample is collected, PCR testing for a cough lasting up to three weeks, and a serological analysis from the second to the eighth week, at most up to the twelfth week. A chest X-ray helps to detect complications, most often pneumonia, but changes are not specific for whooping cough (6). Due to the increasing frequency of respiratory infections, the role of the chest X-ray is considered for their diagnosis, including the diagnosis of pertussis.

The aim of this review article is to analyze the advantages and disadvantages of X-ray diagnostics in patients with whooping cough.

Methods

In this review article, the electronic databases were searched using Google Scholar advanced search, as well as the Serbian Library Consortium for Coordinated Acquisition – KoBSON and the PubMed platform. The following keywords were used: chest X-rays, diagnosis, whooping cough, advantages and disadvantages. Publications published from 2014 to 2024 in Serbian and English were used. The results of studies conducted on the topic of X-ray diagnostics in cases of whooping cough are presented in a narrative form.

Epidemiological and clinical characteristics of whooping cough

The World Health Organization (WHO) describes whooping cough as "a highly contagious disease of the respiratory tract caused by *Bordetella pertussis*", which is a particularly pathogenic microorganism for humans. Whooping cough affects people of all ages, especially children and it is one of the leading causes of death in children under one year of age. Incubation usually lasts 7 to 10 days (from one to three weeks), and clinical manifestations are related to age and vaccination status (4). In children, the disease is characterized by paroxysmal cough that is accompanied by characteristic inspiratory wheezing and posttusive vomiting. Also, cyanosis, dyspnea and apnea may occur. Adolescents and adults usually have atypical symptoms and may only have a persistent cough. The severity of disease is inversely proportional to the age of the patient (7). Namely, pertussis has a predictable course in unvaccinated children and can result in a clinical course followed by complications. The prognosis is particularly bad during the first and second year of life, when the frequency of hospitalization and deathly outcomes is the highest (0.2% in developed and 4% in underdeveloped countries) (8). The disease may have a mild and atypical course in vaccinated children, adolescents and adults, which is why it is rarely detected in these people. Namely, these patients can be a significant source of infection for young children, especially children in the first year of life, when the immune system is still not sufficiently developed (4). Several seroepidemiology studies have shown that the disease is very common in teenagers and adults (7,9), that is, that they are important sources of infection for young children.

Pertusis kod pacijenata sa hroničnim bolestima, kao što su astma ili hronična opstruktivna bolest pluća, može dovesti do komplikacija i povećanih troškova lečenja (14). Nedavna procena ukazuje da 60% starijih osoba u Evropi ima barem dve hronične bolesti (15), što ih uz nedostatak ili nepotpunu imunizaciju i slabiji imunitet čini osetljivijim na infektivne bolesti i povećava rizik od komplikacija. Osim toga, pertusis može biti neposredni uzročnik drugih bolesti.

Testiranje na pertusis korišćenjem PCR metode i/ili serologije, koje može dati laboratorijsku potvrdu, nije uvek dostupno u okviru primarne zdravstvene zaštite, kao ni u okviru pojedinih urgentnih službi. Takođe sporo rastuća *Bordetella* zahteva specijalizovane medije (hranjive podloge), a kulture obično nisu pozitivne 3 do 7 dana. Kod odraslih osoba, u trenutku kada se sumnja na dijagnozu, kulture su obično negativne (16). PCR ima veću senzitivnost i specifičnost od kulture, ali testiranje nije široko dostupno.

Diferencijalno dijagnostički, veliki kašalj treba uzeti u obzir kod pacijenata sa produženim kašljem, posebno ukoliko se javlja u paroksizmima ili uz „zvuk“ pri udahu ili povraćanje posle kašlja. Tokom rane paroksizmalne faze, leukocitoza (često 25.000 do 60.000 po mL) sa limfocitozom može povećati sumnju na pertusis (17). Nalazi radiografije pluća nisu specifični i mogu pokazati peribronhijalno zadebljanje (muf), naglašen retikularni crtež perihilarno, konsolidacije plućnog parenhima, atelektaze različitog stepena i limfadenopatiju.

SZO procenjuje da je širom sveta bilo 151.074 slučajeva velikog kašlja u 2018. godini, a u prethodnim godinama (2008) prijavljeno je do 89.000 smrtnih slučajeva. Trenutno je vakcinacija (korpuskularna i manje reaktogena acelularna) najbolja dostupna strategija za redukcuju broja obolelih od velikog kašlja (1,18). Međutim, i pored globalne vakcinacije ova bolest danas nije eliminisana, nego je ostala endemična u većini zemalja. Razlozi oživljavanja bolesti nisu jasni, a neki navode genetsku adaptaciju cirkušućih prouzrokovaća pertusisa na vakcinu, kratko trajanje imuniteta posle date acelularne vakcine, smanjen obuhvat vakcinacije dece, neuspeh vakcina da spreče nastajanje i prenos infekcije. U cilju rešavanja novnastale situacije predlaže se vakcinacija novorođenčadi, uvođenje buster doze vakcine za decu do 14. godine života, kao i vakcinisanje trudnica (19-21). Pravovremeno ordiniranje antibiotika doprinosi da osoba nije zarazna posle petog dana od uzimanja terapije, a bez antibiotske terapije zarazna je tri nedelje.

Prednosti rendgenske dijagnostike kod pacijenata sa velikim kašljem

Ministrstvo zdravlja Republike Srbije i dostupni protokoli za dijagnostiku velikog kašlja preporučuju da se rendgensko snimanje grudnog koša uradi kod pacijenata mlađih od četiri godine sa sumnjom na veliki kašalj, kako bi se olakšala dijagnoza i detektovale eventualne komplikacije. Glavni razlog za rendgen pluća dece sa sumnjom na veliki kašalj je olakšavanje dijagnoze kod dece mlađe od 4 godine, jer su simptomi nespecifični, a rendgenski snimak može pomoći u proceni stanja pluća i eliminaciji drugih uzroka respiratornih problema kao što su pneumonija i bronhitis, koji mogu biti posledica ili komplikacija velikog kašlja. Takođe, rendgen pluća se koristi za detekciju komplikacija velikog kašlja (pneumonija, atelektaza pluća, itd.). Kod postojanja serije neprestanih napada kašlja (paroksizmalnog kašlja) rendgenski snimak pluća omogućava sagledavanje težine stanja i prisutnih plućnih komplikacija. Takođe, kod mlađih pacijenata rendgenski snimak doprinosi isključivanju drugih respiratornih bolesti koje imaju slične simptome kao veliki kašalj (npr. bronhiolitis ili pneumonija).

Ipak, uprkos ovim preporukama, oko 20% pacijenata, uzrasta od 0-2 godine, uključenih u istraživanje Lime i saradnika (2022) nije imalo urađene rendgenske snimke pluća, što je možda posledica neinformisanosti zdravstvenih radnika o ovoj preporuci (22). Ipak, pomenuta studija takođe je indentifikovala promene kod 57,5% pacijenata sa rendgenskim snimcima pluća, pri čemu su se najčešće javljali peribronhijalno zadebljanje i naglašen perihilarni retikularni crtež. Naime, malo studija opisalo je promene na rendgenskim snimcima kod pacijenata sa sumnjom na veliki kašalj. Ipak, najčešći nalazi na rendgenskim snimcima pluća kod pacijenata sa akutnim respiratornim infekcijama su: peribronhijalno zadebljanje, naglašen retikularni crtež perihilarno i konsolidacije plućnog parenhima (23).

Zadebljanje peribronhijalnih struktura je često prisutno kod pacijenata sa velikim kašljem. Na rendgenskom snimku, zadebljani peribronhijalni prostor ili peribronhijalni muf će se najbolje prikazati kada je periferni bronh ortogonalno pogođen

Pertussis infection has shown immunomodulatory effects, with recent research focusing on the role of adenylate cyclase toxin (CyaA) and type III secretion system proteins (TTSS) that can influence the pathogenesis of underlying chronic conditions/diseases, especially chronic inflammatory diseases (10,11). There is evidence that infection caused by *Bordetella pertussis* can have an impact on asthma attack (12), respiratory diseases (10) and other atopic conditions (13).

Pertussis in patients with chronic diseases, such as asthma or chronic obstructive pulmonary disease, can lead to complications and increased treatment costs (14). A recent estimate indicates that 60% of the elderly in Europe have at least two chronic diseases (15), which together with the lack of immunization or incomplete immunization and weak immunity make them more susceptible to infectious diseases and increase the risk of complications. In addition, pertussis can be a direct cause of other diseases.

Testing for pertussis using the PCR method and/or serology, which can provide laboratory confirmation, is not always available within primary health care, as well as within certain emergency services. Also, slow-growing *Bordetella* requires specialized media (nutritious base), and cultures are typically not positive for 3 to 7 days. In adults, by the time the diagnosis is suspected, cultures are typically negative (16). PCR is more sensitive and specific than culture, but testing is not widely available.

In terms of differential diagnosis, whooping cough should be considered in patients with prolonged cough, especially if it occurs in paroxysms or with a "sound" while inhaling or post-tussive emesis. During the early paroxysmal phase, leukocytosis (often 25,000 to 60,000 per mL) with lymphocytosis may raise suspicion for pertussis (17). Chest X-ray findings are not specific and may show peribronchial thickening (cuffing), prominent reticular pattern in the perihilar area, consolidation of lung parenchyma, variable degrees of atelectasis and lymphadenopathy.

The WHO estimates that there were 151,074 cases of whooping cough worldwide in 2018, while in previous years (2008), up to 89,000 deaths were reported. Currently, vaccination (corpuscular and less reactogenic acellular) is the best available strategy to reduce the number of people who get whooping cough (1,18). However, despite global vaccination, this disease has not been eliminated so far, but has remained endemic in most countries. The reasons for the resurgence of the disease are not clear, and some cite the genetic adaptation of circulating pertussis agents to the vaccine, the short duration of immunity after the acellular vaccine, the reduced coverage of children with vaccine, the failure of vaccines to prevent the development and transmission of infection. In order to solve the new situation, the vaccination of newborns has been proposed, as well as the introduction of booster dose for children up to 14 years of age and the vaccination of pregnant women (19-21). The timely administration of antibiotics contributes to the fact that a person is not contagious after the fifth day of taking therapy, and without antibiotic therapy, he is contagious for three weeks.

The advantages of X-ray diagnostics in patients with whooping cough

The Ministry of Health of the Republic of Serbia and available protocols for the diagnosis of whooping cough recommend that chest X-rays should be performed in patients younger than four years with suspected whooping cough, in order to make diagnosis easier and detect possible complications. The main reasons for the chest X-ray of children with suspected whooping cough is to make the diagnosis easier in children under four years of age, because the symptoms are non-specific, and the X-ray can help assess the state of the lungs and eliminate other causes of respiratory problems – pneumonia, bronchitis, which may be the result or complication of whooping cough. Also, the chest X-ray is used to detect complications of whooping cough (pneumonia, lung atelectasis, etc.). In the presence of a series of continuous coughing fits (paroxysmal cough), a chest X-ray enables the evaluation of the severity of the condition and present pulmonary complications. Also, in younger patients, a chest X-ray helps to distinguish pertussis from other respiratory diseases that have similar symptoms as whooping cough (e.g. bronchiolotis or pneumonia).

However, despite these recommendations, about 20% of patients, aged 0-2 years, included in the study of Lima et al. (2022) did not have the chest X-ray done, which may be the consequence of the fact that healthcare workers were uninformed about these recommendations (22). However, the

X zrakom i to u vidu kružnog rasvetljenja sa zidom koji je veće debljine nego što je to uobičajeno i to zbog inflamacije i otoka okolnih tkiva (24). Ovaj nalaz može biti posledica direktnog prisustva infekcije u respiratornom sistemu pacijenta, ali može se javiti i zbog upale koja nastaje usled mehaničke iritacije zida bronha uzrokovane napadima kašlja tokom pertusisa. Pored zadebljanja peribronhijalnih struktura, moguće je da se na rendgenskim slikama vide i druge promene karakteristične za veliki kašalj.

Atelektaza (kolaps plućnih alveola) i alveolarna zasenčenja (nakupljanje tečnosti ili supstanci u plućnom parenhimu) takođe mogu biti prisutne na rendgenskom snimku pluća pacijenata obolelih od pertusisa. Atelektaza je česta komplikacija bolesti koja se javlja kao rezultat povećanog pritiska u alveolama tokom jakih i dugotrajnih napada kašlja, što rezultira njihovim kolapsom i ograničenom razmenom gasova u njima. Na rendgenskom snimku, atelektaza se manifestuje smanjenom transparentnošću parenhima koja zapravo predstavlja segment pluća bez vazduha (25). Atelektaza može biti segmentna, lobarna ili kompletna, u zavisnosti od toga koliko područje pluća je zahvaćeno (23). Segmentna i lobarna atelektaza se na radiografiji pluća prikazuju kao trouglasta mekotkivna zasenčenja čija se baza nalazi na periferiji, a vrh je usmeren ka hilusu. U težim slučajevima, može doći i do atelektaze celog plućnog krila, što se na snimcima prezentuje u vidu jednostrano tamnog pluća i snažnog privlačenja medijastinalnih struktura ka kolabiranom plućnom krilu. Ovakav nalaz ukazuje na ozbiljan poremećaj u plućnoj funkciji pacijenata obolelih od velikog kašlja (25). Posledično, atelektaza može dovesti do smanjenog protoka kiseonika u organizmu, što se manifestuje nedostatkom daha, umorom i slabošću.

Alveolarna zasenčenja su takođe česti nalazi na rendgenskom snimku pluća pacijenata obolelih od velikog kašlja (16). Ona predstavljaju nakupljanje tečnosti ili supstanci u plućnom parenhimu. Sama *Bordetella pertussis* može svojim toksinima i drugim metaboličkim produktima izazvati upalu i iritaciju bronha, što dovodi do povećane proizvodnje sluzi. Alveolarna zasenčenja kao forma razvijene bolesti na rendgenskom snimku se vide kao slivena, ređe pojedinačna mrljasta zasenčenja plućnog parenhima i znak su uznapredovaloginflamatornog procesa. Skenerom mogu da se vide razliličite atenuacije ili smanjenja transparencija plućnog parenhima od tipa mlečnog stakla pa do pravih konsolidativnih promena. Rendgenski se promene tipa mlečnog stakla mogu previdеti ukoliko zahvataju manju površinu parenhima. Zbog ograničenog protoka vazduha i neefikasne razmene gasova, alveolarne infiltracije se klinički manifestuju simptomima kao što su nedostatak daha, kašalj i otežano disanje.

Međutim, treba naglasiti da rendgenski snimak pluća nije specifičan test za dijagnozu velikog kašlja, ali u svim gore navedenim primerima može da pomogne da bi se pravovremeno postavila dijagnoza i započelo sa terapijom.

Nedostaci rendgenske dijagnostike kod pacijenata sa velikim kašljem

Jedan od glavnih problema prilikom rendgenskog snimanja pacijenata sa velikim kašljem je napad kašlja tokom samog postupka snimanja. Ovo može dovesti do artefakata koji otežavaju interpretaciju nalaza. Samim tim, zbog lošeg kvaliteta slike može postojati potreba za ponavljanjem snimanja, što može biti iscrpljujuće i neprijatno iskustvo za pacijenta koji ne može da kontroliše napad kašlja.

Najveći procenat pacijenata sa velikim kašljem čine deca mlađeg uzrasta kod kojih je nemoguće vizualizovati oko 22% plućnog parenhima zaklonjenog srčano-sudovnom senkom na rendgenskom snimku. Nedostatk saradnje pacijenta prilikom snimanja, u smislu odsustva maksimalnog inspirijuma prilikom ekspozicije, čini ovaj procenat još većim (23).

Još jedan nedostatak rendgenskog snimanja kod pacijenata sa velikim kašljem jeste i neefikasnost u otkrivanju bolesti u ranom stadijumu, iako može biti koristan za detekciju kasnijih komplikacija, kao što su upala pluća ili pneumotoraks. Naime, u ranom stadijumu bolesti, kašalj može biti blag ili sličan običnom kašlju kod prehlade. Ove početne faze mogu biti presudne za pravovremenu dijagnozu i započinjanje odgovarajućeg lečenja kako bi se sprečilo dalje širenje bolesti. Međutim, rendgensko snimanje obično nije dovoljno osetljivo da detektuje blage promene koje se javljaju tokom ovog perioda.

Kada je reč o rendgenskom snimanju, jedan od nedostataka je i izlaganje pacijenta jonizujućem zračenju koje ima potencijal da ošteti ćelije u telu. Preterana izloženost ovom zračenju može povećati rizik od razvoja karcinoma i drugih bolesti. U slučaju velikog kašlja, gde rendgensko snimanje

above mentioned study also identified changes in 57,5% of patients with the chest X-ray, where peribronchial thickening and prominent perihilar reticular pattern occurred most often. Namely, few studies described X-ray changes in patients with suspected whooping cough. However, the most common findings on chest X-ray in patients with acute respiratory infections are the following: peribronchial thickening, prominent reticular pattern in the perihilar area and consolidation of lung parenchyma (23).

Thickening of peribronchial structures is often present in patients with whooping cough. On the chest X-ray, thickened peribronchial space or peribronchial cuffing will be best shown when the peripheral bronchus is orthogonally affected by the X-ray, in the form of a ring-like illumination with a wall that is thicker than usual due to inflammation and swelling of the surrounding tissues (24). This finding may be a consequence of the direct presence of infection in the patient's respiratory tract, but it may also occur due to inflammation resulting from mechanical irritation of the bronchial wall caused by coughing fits during pertussis. In addition to the thickening of peribronchial structures, it is possible that other changes characteristic of whooping cough can be seen on X-ray images.

Atelectasis (collapse of lung alveoli) and alveolar opacities (accumulation of fluids or substances in the lung parenchyma) may also be present on chest X-rays in patients with pertussis. Atelectasis is a common complication of the disease that occurs as a result of increased pressure in alveoli during strong and prolonged coughing attacks, which results in their collapse and limited gas exchange in them. On the chest X-ray, atelectasis is manifested as reduced transparency of parenchyma, which is actually a segment of the lung without air (25). Atelectasis can be segmental, lobar or complete, depending on how much of the lung area is affected (23). Segmental and lobar atelectasis appears on chest radiography as wedge-shaped area of soft-tissue opacity, where the apex is at the hilum and base towards the pleura. In more severe cases, there may be atelectasis of the entire lung, which is presented on the X-ray images as a unilateral dark lung and a strong mediastinal shift toward the collapsed lung. This finding indicates a serious disorder in the lung function of patients suffering from whooping cough (25). As a result, atelectasis can lead to a reduced flow of oxygen in the body, which is manifested by shortness of breath, fatigue and weakness.

Alveolar opacities are also common findings on the chest X-ray of patients affected by whooping cough (16). It represents the accumulation of fluids or substances in the lung parenchyma. *Bordetella pertussis*, with its toxins and other metabolic products, can cause inflammation and irritation of bronchi, which causes the increased production of mucus. Alveolar opacities as a form of developed disease on the radiological image are seen as consolidative, less often individual patchy opacities of lung parenchyma and they are a sign of an advanced, inflammatory process. With the CT scan, different attenuations or reductions in the transparency of the lung parenchyma can be seen, from the ground glass opacity to true consolidative changes. Changes such as ground glass opacities can be overlooked on the chest X-ray if they affect a smaller surface of the parenchyma. Due to the limited air flow and less efficient gas exchange, alveolar infiltrations are clinically manifested as shortness of breath, cough or breathing difficulties.

However, it should be emphasized that the chest X-ray is not a specific test for the diagnosis of whooping cough, but in all the above mentioned examples, it can help to make a timely diagnosis and start therapy.

The disadvantages of X-ray diagnostics in patients with whooping cough

One of the main problems when the chest X-ray is done in patients with whooping cough is a coughing fit during the imaging procedure. This can lead to artifacts that make the interpretation of findings difficult. Therefore, due to poor image quality, it can happen that imaging has to be repeated, which can be a tiring and unpleasant experience for a patient who cannot control coughing fits.

The largest percentage of patients with whooping cough are young children, in whom it is impossible to visualize about 22% of the lung parenchyma, which is obscured by the cardiovascular shadow on the X-ray image. The lack of cooperation of patients during imaging procedure in terms of the absence of maximum inspiration during exposure makes this percentage even higher (23).

nije neophodno za dijagnozu u ranim stadijumima, izlaganje pacijenta ovj vrsti zračenja može biti neefikasno i nepotrebno.

Što se tiče interpretacije rendgenskog snimka grudnog koša u dijagnostici velikog kašlja, moguće su određene greške koje mogu uticati na tačnost dijagnoze. Neki od mogućih problema uključuju: nedovoljnu osetljivost, nespecifičnost nalaza, dijagnostičku konfuziju i variranje nalaza tokom bolesti.

Naime, radiografija pluća može biti manje osetljiva za detekciju blagih promena koje se javljaju u ranim stadijumima pertusisa. Ovo može dovesti do lažno negativnih rezultata, gde snimak ne pokazuje prisustvo infekcije i može dovesti do propusta u postavljanju tačne dijagnoze. Takođe, kod pacijenata sa velikim kašljem može pokazivati nespecifične promene, kao što su zadebljanje peribronhovaskularnog crteža ili manja alveolarna zasenčenja. Ove promene nisu specifične za veliki kašalj i mogu se videti i kod drugih respiratornih infekcija ili stanja. Ponekad se simptomi pertusisa mogu preklapati sa drugim respiratornim infekcijama ili bolestima koje imaju sličnu prezentaciju kao što su bronhitis ili astma, te mogu izazvati tzv. dijagnostičku konfuziju. Takođe, veliki kašalj prolazi kroz različite faze tokom vremena, tako da rendgenski nalazi mogu varirati zavisno od stadijuma bolesti. Na primer, početni stadijum bolesti može imati normalan rendgenski nalaz, dok kasnije može doći do konsolidacije. Kako bi se minimizirale greške prilikom interpretacije radiografije pluća kod sumnje na pertusis, važan je sveobuhvatni pristup koji uključuje kliničku istoriju pacijenta, laboratorijske testove i praćenje simptoma tokom vremena kako bi se postavila ispravna dijagnoza i započelo adekvatno lečenje.

Zaključak

Rendgenski snimak pluća kod lica sa sumnjom na veliki kašalj može imati značajnu ulogu u proceni komplikacija i diferencijalnoj dijagnozi. Kod dece mlađe od četiri godine sa sumnjom na veliki kašalj, može se koristi kao dodatni alat za potvrdu ili isključivanje bolesti, ali samo u kombinaciji sa kliničkim i laboratorijskim pristupom.

Konflikt interesa

Autori su izjavili da nema konflikta interesa.

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Another disadvantage of radiological imaging in patients with whooping cough is related to the ineffectiveness to detect the disease at an early stage, although it may be useful for detecting later complications, such as pneumonia or pneumothorax. Namely, in the early stage of the disease, the cough may be mild or similar to coughing which is the symptom of the common cold. These initial stages can be crucial for timely diagnosis and appropriate treatment to prevent further spreading of this disease. However, radiological imaging is usually not sensitive enough to detect mild changes that occur during this period.

When it comes to the radiological imaging, one of the disadvantages is exposing the patient to ionizing radiation that has the potential to damage cells in the body. Excessive exposure to this radiation can increase the risk of developing cancer and other diseases. In the case of whooping cough, where X-ray imaging is not necessary for diagnosis in early stages, exposing the patient to this type of radiation may be ineffective and unnecessary.

As for the interpretation of chest X-ray in the diagnosis of whooping cough, certain errors are possible that can affect the accuracy of the diagnosis. Some of the possible problems include: insufficient sensitivity, non-specificity of findings, diagnostic confusion and variation of findings during the course of the disease.

Namely, chest radiography may be less sensitive for detecting mild changes that occur in the early stages of pertussis. This can lead to false negative results, where the image does not show the presence of infection and can lead to a failure to establish an accurate diagnosis. Also, in patients with whooping cough, it may show non-specific changes, such as thickening of the peribronchovascular pattern or minor alveolar shadows. These changes are not specific for whooping cough and they can be seen in other respiratory infections or conditions. Sometimes the symptoms of pertussis can overlap with other respiratory infections or diseases that have a similar presentation such as bronchitis or asthma, and can cause the so-called diagnostic confusion. Also, whooping cough goes through different stages over time, so X-ray findings can vary depending on the stage of the disease. For example, the initial stage of the disease may have a normal X-ray finding, while later consolidation may occur. In order to minimize errors in the interpretation of chest radiography in patients with suspected pertussis, a comprehensive approach is necessary, which includes the patient's clinical history, laboratory tests and monitoring of symptoms over time in order to establish the correct diagnosis and start adequate treatment.

Conclusion

The chest X-ray in persons with suspected whooping cough can play a significant role in the evaluation of complications and differential diagnosis. In children younger than four years with suspected whooping cough, it can be used as an additional tool to confirm or exclude the disease, but only in combination with a clinical or laboratory approach.

Competing interests

The authors declared no competing interests.

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