

Josef Brudzinski and Vladimir Mikhailovich Kernig: Signs for Diagnosing Meningitis

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Inflammation of the meninges, or meningitis, is a serious neurological insult that involves the membranes (dura, pia and arachnoid matter) covering the brain and spinal cord. Meningitis may be caused by any of a host of infectious and non-infectious agents including bacteria, viruses, fungi, parasites, drugs, autoimmune disorders, or malignancy which considerably influences morbidity and mortality.¹ Currently, the case-fatality rate for adults with bacterial meningitis is approximately 25% with temporary or permanent neurologic sequelae occurring in 21% to 28% of survivors.^{2,3} These rates are slightly lower for children older than 1 month, but remain significant, and early diagnosis is critical in improving outcomes.^{4,5}

Symptoms of acute meningitis include high fevers, chills, joint pain, decreased mental status, headache (“worst headache of my life”), stiff neck, photophobia, and rash. Early indicators such as rash or joint pain may present abruptly depending on the etiologic agent. One study reported that initial symptoms appear on average 24 hours prior to hospital admission.⁶ A major predictor of outcome in patients diagnosed with bacterial meningitis is the time that has elapsed from the onset of symptoms to the initiation of antibiotic treatment.^{2,7,8} Empiric treatment with selected antibiotics is based on age of the patient and associated co-morbidities.

Critical and timely diagnosis may be facilitated by Kernig’s and Brudzinski’s signs. These two eponyms are commonly associated with meningitis.

Kernig’s Sign

Vladimir Mikhailovich Kernig (1840-1917) was a Russian-Baltic German clinical neurologist born in Lapaia, Latvia. He received the majority of his education at the Russian University. After receiving his medical doctorate in 1865, Kernig joined the Obuchow Hospital in St. Petersburg as a voluntary assistant physician. He later became a clinical teacher of Internal Medicine at the Empress Marie’s institutions, a school for the deaf and mute, and was the head physician at Obuchow Women’s Hospital from 1890 until World War I.^{9,10}

Kernig's sign was first described in 1882 in an article from the St. Petersburg Medizinische Wochenschrift (German weekly medical writing) in which he stated:

"I have observed for a number of years in cases of meningitis a symptom which is apparently rarely recognized although, in my opinion, it is of significant practical value. I am referring to the occurrence of flexion contracture in the legs or occasionally also in the arms which becomes evident only after the patient sits up; the stiffness of neck and back will ordinarily become much more severe and only now will a flexion contracture occur in the knee and occasionally also in the elbow joints. If one attempts to extend the patient's knees one will succeed only to an angle of approximately 135°. In cases in which the phenomenon is very pronounced the angle may even remain 90°."¹¹

Today the maneuver is performed with the patient in the supine position with hips and knees in flexion. The patient's knee is slowly extended; pain (spasms) involving the hamstring muscles as a result of stretching the inflamed sciatic nerve roots at angles less than 135°, with the popliteal fossa serving as the inner angle, constitutes a positive Kernig's sign¹⁰ (figure 1). Kernig did not describe pain in the original description of the maneuver.^{10,11} Nonetheless, many clinicians include pain as a required component constituting a positive test.¹⁰

Brudzinski's Sign

Josef Brudzinski (1874-1917), a Polish born pediatrician, also studied at the Russian University of Dorpat, and then practiced medicine in Poland. Dr. Brudzinski was an active leader in the medical and political community. After obtaining his medical degree in 1897, Brudzinski went to Germany to conduct research with Theodor Escherich, a pioneer in the field of pediatric infectious diseases.¹² His work contributed to making the Anne Marie Children's Hospital in Lodz, Poland a model hospital of its time. In 1908, he launched



Figure 1. Kernig's sign. Flexing a patient's hip, then extending the knee causes pain at angles less than 135° with the popliteal fossa as the inner angle.



Figure 2. Brudzinski's sign. After passive flexion of the patient's neck, there is flexion of the hips and knees.

Poland's first journal of pediatrics, *Przegląd Pedyatryczny*, followed in 1910 by designing a children's hospital in Warsaw, Poland according to his own specifications. A separate outpatient clinic entrance, purposely constructed without hospital access, successfully prevented the spread of infections.¹³ Without question this blueprint spared large numbers of children from being exposed to diseases easily transmitted through airborne pathogens. Brudzinski was instrumental in reestablishing the Polish university in Warsaw after German occupancy during World War I and was named director at its 1915 opening.

Ahead of his time, Brudzinski relied on laboratory studies to provide explanations for the mechanisms of the numerous meningeal signs he described, specifically conducting experiments on different species of animals.¹⁰ Brudzinski developed four maneuvers to detect meningitis: the obscure Cheek sign, Symphyseal sign, Brudzinski's reflex, and the famous Brudzinski (nape of the neck) sign. A positive Cheek sign is elicited by placing pressure on both cheeks inferior to the zygomatic arch causing spontaneous flexion of the forearm and arm.¹⁰ A positive Symphyseal sign occurs when pressure applied to the pubic symphysis elicits a reflex hip and knee flexion, and abduction of the leg. Both of these signs were most commonly observed in children with meningitis caused by *Mycobacterium tuberculosis*.¹⁰ Brudzinski's reflex consists of passive flexion of one knee into the abdomen eliciting flexion of opposite hip and knee.¹¹ His most famous maneuver is aptly referred to as Brudzinski's sign and is performed with the patient in the supine position. The examiner, with one hand behind the patient's head and the other on their chest, raises the patient's head while the other hand prevents the patient from rising. It is theorized that in meningitis, passive flexion of the neck stretches the nerve roots through the meninges, both of which are inflamed, causing pain and involuntary movement of lower extremities. Therefore, flexion of the patient's hips and knees after passive flexion of the neck constitutes a positive Brudzinski sign^{9,10} (figure 2).

Relationship Between Pathogen and Sensitivity of Signs

In Brudzinski's 1909 paper entitled "Über die kontralateralen Reflexe an den unteren Extremitäten bei Kindern" ("A New Sign of the Lower Extremities in Meningitis of Children"), the sensitivities of Brudzinski's and Kernig's signs were 97% and 42%, respectively.¹¹ These findings were met with much opposition by his colleagues, but Brudzinski confirmed the high specificity of his sign by being unable to elicit it in children without meningitis.¹⁴ One cannot help but notice that these early sensitivities found by Brudzinski are much higher than what has been reported in more recent literature.¹⁵⁻¹⁸ Some attribute this to the fact that the two most common causes of meningitis during this time were *Streptococcus pneumoniae* and *M. tuberculosis*. The severe inflammation response that accompanies infection with *S. pneumoniae* likely plays a role in explaining the high mortality rates associated with pneumococcal infection (28%) as compared to meningococcal infection (11%) and Haemophilus infection (3-6%).^{19,20} Since Kernig's and Brudzinski's signs are related to inflammation of the meninges and nerve roots, the severity of inflammation that occurs in bacterial meningitis would likely result in greater sensitivity of the signs.^{11,14} The severity of nuchal rigidity, an indicator of meningeal irritation and probable inflammation, is also greater in tuberculous meningitis compared to other forms of pyogenic meningitis.²¹ A retrospective study conducted by van Well et al²² found meningeal irritation present in 98% of 554 patients with tuberculous meningitis. Furthermore, the progression of tuberculous meningitis is much slower than bacterial meningitis, resulting in a more advanced stage of the disease at presentation and initiation of treatment, increasing the likelihood that a patient would present with a positive Kernig's and/or Brudzinski's sign.²¹

The majority of examined patients described in Kernig's and Brudzinski's original papers were children; the population most frequently affected by tuberculous meningitis.²² Out of 554 patients with tuberculous meningitis in the van Well study, 82% were <5 years old.²² Moreover, the prevalence of tuberculosis in Western Europe peaked in the early 1800s and was the largest cause of death at the time. In the next 100 to 200 years tuberculosis spread to Eastern Europe, including Latvia and Poland, where Kernig and Brudzinski were conducting their research.^{23,24} In fact, Brudzinski noted 21 cases of tuberculous meningitis in his original description of 42 cases of meningitis.¹¹

Age Related Differences in Presentation

It is important to note that Brudzinski, a pediatrician, and Kernig, a school physician, likely collected their anecdotal evidence through examination of children school-aged and younger. While the majority of the cases of meningitis occur in children under the age of two, with a peak incidence occurring at three to eight months of age, Kernig's sign, Brudzinski's sign, and nuchal rigidity are not accurate in diagnosing meningitis in infants younger than six

months.^{15,19,25} In a study conducted by Guraraj et al,¹⁸ Brudzinski's and Kernig's signs were found to be positive in only 18% and 19%, respectively, of children with meningitis. Furthermore, the absence of the meningeal irritation in infants less than one month old resulted in incorrect diagnoses.^{26,27} In a retrospective study conducted by Levy and Fried,¹⁵ as the age of patients with bacterial meningitis increased (from 2-24 months to 5-12 years), the sensitivity of Kernig's and Brudzinski's signs also increased. In another study conducted by Chotpitayasunondh,²⁸ the sensitivity of Brudzinski's sign was again found to increase with age of patients with bacterial meningitis (11.5% in neonates, 74.8% >1 month). As a result, Brudzinski's and Kernig's signs are not as frequently applied to young children as they are to adolescents and adults.²⁹ Kernig's and Brudzinski's signs have also been proven ineffective in elderly populations.^{15,21,26} In a study conducted by Puxty et al,³⁰ Kernig's sign was positive in 12% and Brudzinski's sign in 8% of geriatric patients without meningitis. Nuchal rigidity has been found to occur in up to 30% of the elderly population in the absence of meningitis.³¹ The presence of nuchal rigidity in the absence of meningitis, coupled with the increased prevalence of viral meningitis (less severe symptoms) and other underlying disease in geriatric patients, supports the general consensus that the diagnosis of meningitis in this population through the use of meningeal signs is inaccurate and ineffective.³²

Sensitivity and Specificity of Kernig's and Brudzinski's Signs

Evaluation of the sensitivity and specificity of Kernig's sign does not adjust for the differences in current procedure of eliciting the sign from the original procedure as outlined by Kernig.¹⁰ In his original description he stated, "I am referring to the occurrence of flexion contractures in the legs or occasionally also in the arms which become evident only after the patient sits up," and "spasms in the extremities of recumbent patients are, as far as I have seen, present only intermittently."²³ While he performed the sign in patients sitting upright, textbooks of clinical medicine, pediatrics, and neurology routinely describe performing the test with the patient in the supine position. The advantage of evaluating neck stiffness in the sitting posture has been reproduced.³³ In contrast, Brudzinski's sign is performed in the same fashion originally described. This equitable comparison may account for the reported discrepancy that Brudzinski's sign is often more sensitive than Kernig's sign.^{9,10,15}

Surprisingly, there are few studies that explore the diagnostic efficacy of Kernig's and Brudzinski's signs. In 1999, a comprehensive review of all studies exploring the accuracy and precision of the clinical examination in the diagnosis of adult meningitis found only one study in which 34 cases of adult meningitis were analyzed and reported a sensitivity of 9% and specificity of 100% for Kernig's sign.^{14,16} It should be noted that this study excluded patients presenting with focal neurologic findings and mental status abnormalities, thus potentially excluding patients with a high likelihood of

meningitis. Therefore, this study underestimated the diagnostic sensitivity of this sign. However, a more recent study, by Thomas et al¹⁷ analyzing 297 adults with suspected meningitis reported a sensitivity of 5% and specificity of 95% for both Kernig's and Brudzinski's signs.

These studies suggest that Kernig's and Brudzinski's signs are insensitive for detecting meningitis and therefore, when not present, should not be used to exclude the diagnosis of meningitis. The high specificity suggests that if Kernig's or Brudzinski's sign is present, there is a high likelihood for meningitis. In Kernig's original description of his sign in advanced cases of meningitis, pain may be elicited at angles of extension less than 90°, suggesting that the sensitivity of the sign may vary proportionately with severity of disease. However, Thomas et al¹⁷ showed that the sensitivities of Kernig's and Brudzinski's signs are not positively associated with the severity of the disease in subsets of patients with moderate meningeal inflammation or microbiological evidence of central nervous system infection. Additional studies evaluating the meningeal signs in certain subpopulations with meningitis are needed to determine their sensitivity and usefulness, as well as determine if there is a positive association between their sensitivity and severity of disease.

Conclusion

We may tend to overlook or underestimate the contributions of those astute clinicians of the past who, with minimal technology and no sophisticated laboratories at their disposal, built the foundation of clinical medicine through emphasis on the importance of the patient's history and physical examination. Although both Kernig's and Brudzinski's signs have low sensitivity but high specificity for diagnosis of bacterial meningitis, they have contributed to the construction of scoring algorithms incorporating meningeal signs and symptoms, working toward a standard of care to determine the need for lumbar puncture and empiric antibiotic therapy. Further prospective studies to evaluate the sensitivity and specificity of both Brudzinski's and Kernig's signs in various subpopulations (children, adults, geriatrics) need to be conducted. Positive elicitation of Brudzinski's and/or Kernig's signs in clinical evaluation of a patient suspected of meningitis can be confidently regarded as sufficient reason for proceeding with a lumbar puncture and treatment considerations; however, absence of these signs should not be used to rule out (exclude) the diagnosis of meningitis.

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