

Biological Characteristics of Schmallenberg Virus - an Overview

Shalala Zeynalova^{1*}, Asaf Omarov²

¹Azerbaijan, Ministry of Agriculture, 3-rd Biosafety Level Central Reference Laboratory;

²Life Sciences Department, Khazar University

*Corresponding author: shzeynalova@mail.ru

Abstract

Schmallenberg virus disease was originally reported in Germany in 2011. The new disease was diagnosed in the UK in January 2012. Currently, little information has been collected about the pathogen of the Schmallenberg virus. The virus genetically belongs to the Bunyaviridae family (Orthobunyavirus genus and Simbu serogroup). The clinical symptoms of acute SBV infection are unspecific in sheep and goats. This study characterized the origin, emergence, transmission, spread in Europe and Azerbaijan, clinical signs, and the diagnosis of this virus. Currently, the Shmallenberg disease is known to be a serious threat to Veterinary Public Health.

Keywords: Schmallenberg virus, trans missive infections, spread, Azerbaijan

Introduction

Structure of the virus

Schmallenberg Virus (SBV) is an infectious disease of ruminants. The virus belongs to the *Orthobunyavirus* genus of the *Bunyaviridae* family, the Simbu serogroup. Besides the *Orthobunyavirus* genus, the *Bunyaviridae* family has more than 350 viruses divided into five genera based on serological, morphological, and biochemical characteristics: Nairovirus, Phlebovirus, Hantavirus, and Tospovirus with additional unclassified viruses (Charles, 1994; ICTVI, 2006). Although viruses in the Bunyaviridae family share a tripartite RNA genome in common, they significantly differ in their geographic distribution, disease characteristics, and transmission mode (Bishop & Beaty, 1988; Charles, 1994; Horne & Dana, 2014). Viruses within the Orthobunyavirus, Nairovirus, and Phlebovirus genera are transmitted by hematophagous arthropods, whereas hantaviruses are transmitted among rodents, and tospoviruses are transmitted between plants by non-hematophagous thrips (Horne & Dana, 2014; ICTVI, 2006).

A little information has been collected on the pathogen of the Schmallenberg virus, at the moment. These are a single-stranded, negative-sense, tripartite RNA genomes with viral genes on one of three segments: the negative sense large (L) segment, coding for the RNA-dependent RNA polymerase for transcription and replication; the negative sense or ambisense (tospovirus) medium (M) segment, which encodes the Gn and Gc viral glycoproteins and a non-structural protein (NSm). Surface proteins are involved in attachment, cell fusion, and hemagglutination; therefore, they contain important determinants of virulence. Neutralizing antibodies are directed against the epitopes of the surface glycoproteins G1 and G2, while antibodies to the glycoprotein G2 have protective properties (Fischer *et al.*, 2013; Coupeau *et al.*, 2013). The composition of virionic lipids corresponds to the composition of the cell membranes, which is used for culturing the virus (Hofmann *et al.*, 2012; Martinelle *et al.*, 2017).

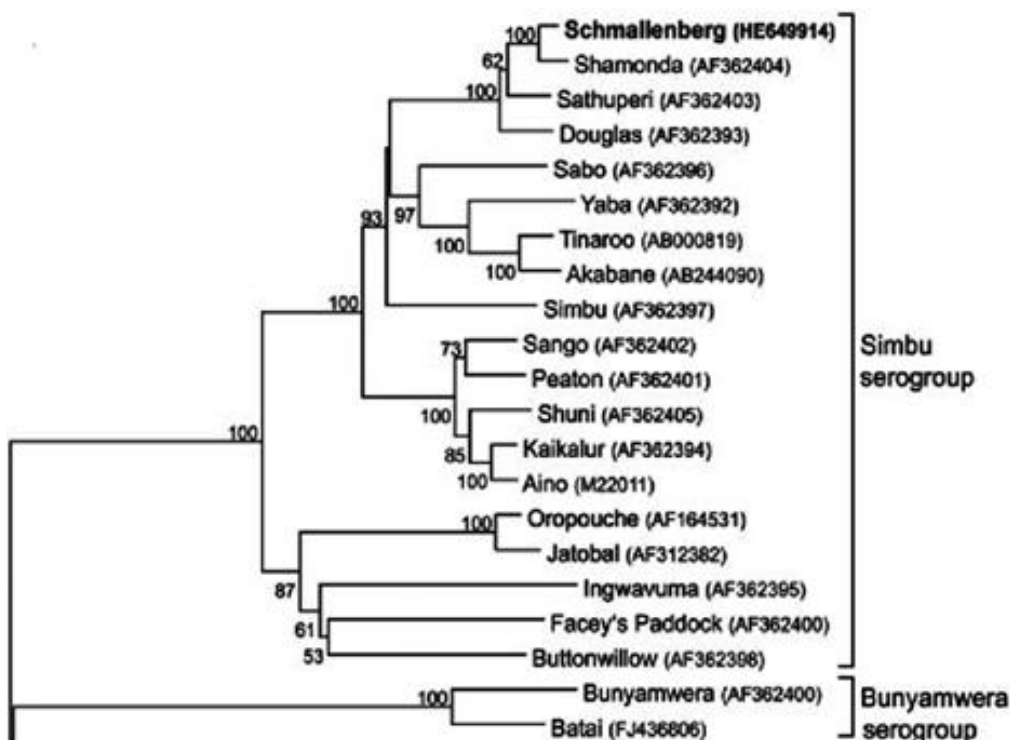


Figure1. Phylogenetic relationship between the Schmallenberg virus and orthobunyaviruses of the Simbu, Bunyamwera, and California serogroups, adapted from Hoffmann *et al.* (2012).

The most famous representatives of this group are the Crimean-Congolese hemorrhagic fever virus, the Nairobi disease virus, the Akabane disease virus, Rift Valley fever virus (Saeed *et al.*, 2001; Goller *et al.*, 2012; Kirkland, 2015). A part of the viruses of this family is susceptible to humans, and a fatal outcome is possible. Bunyaviruses are thermosensitive, i.e. they are quickly inactivated at a temperature of 56 ° C, die when irradiated with ultraviolet rays, sensitive to fat solvents and detergents, acids (Yanase *et al.*, 2012; Elliott, 2009; Sanders *et al.*, 2011).

Spread of Shmallenberg virus

This group of bunyaviruses is more often allocated to the African continent where they were found, and also in the countries of Asia and Australia. However, some of them have been circulating in Europe for several decades (Elliott, 2009; Elbers *et al.*, 2011; Stokes *et al.*, 2015). The first reports of unidentified disease of dairy cattle were obtained from farms located in the Netherlands and Germany (in the city of Schmallenberg were discovered three dairy cows with unexplored symptoms) in August 2011 (Tarlinton *et al.*, 2012; De Regge *et al.*, 2013; Wernike *et al.*, 2014; Berhanu *et al.*, 2018). This new virus named after a German city where infects ruminant artiodactyls (cattle, sheep, goats) has been detected in 7 EU countries: Germany, the Netherlands, Great Britain, France, Luxembourg, Italy, and Belgium (Hofmann *et al.*, 2012; SVE, 2014; Gubbins *et al.*, 2014; Brülisauer *et al.*, 2017). There is a tendency towards the territorial and quantitative spread of infection, both in the number of dysfunctional sites and in the number of infected animals in these countries (ProMED, 2012; Tarlinton *et al.*, 2012; Briese *et al.*, 2013; Bilk *et al.*, 2012).

According to the source, TSN FEDERAL state reporting system, as of March 14, 2012, 944 confirmed cases of Schmallenberg virus were detected in livestock enterprises in Germany in federal lands, of which 124 cases were detected in livestock enterprises where cattle are kept, 780 cases in sheep farms and 40 - goat-breeding enterprises (according to publications of the Friedrich Lefler German Institute) (Lievvaart-Peterson *et al.*, 2012; Conraths *et al.*, 2013).

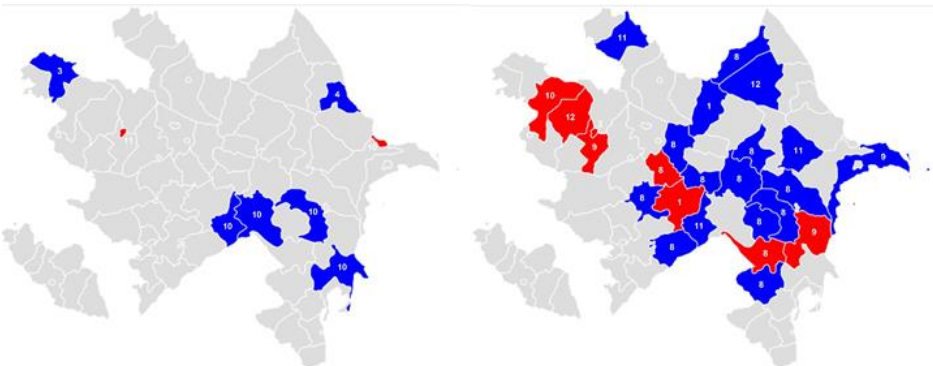
The high SBV within-flock seroprevalence (up to 98.03%) in geographic areas having reported SBV outbreaks in late 2011 and 2012 was expected to limit the reemergence of the virus in 2012 (Wernike *et al.*, 2014; EFSA, 2014)



Figure 2. Geographical spread of SBV in Europe

The occurrence of Shmallenberg diseases in Azerbaijan

In 2012, there was an unexpected increase of abortions in cattle and sheep in Azerbaijan, which was unrelated to infections with Brucella or Chlamydia. Due to the similarities of the overall symptomology observed, the then just recently described Schmallenberg virus was suspected as a potential cause. This surveillance study was hence launched to determine if the Schmallenberg virus had made it to Azerbaijan and to monitor the situation (Gubbins *et al.*, 2014; Zeynalova & Vatani, 2019).



2012/13 October – June 2013/14 July – June

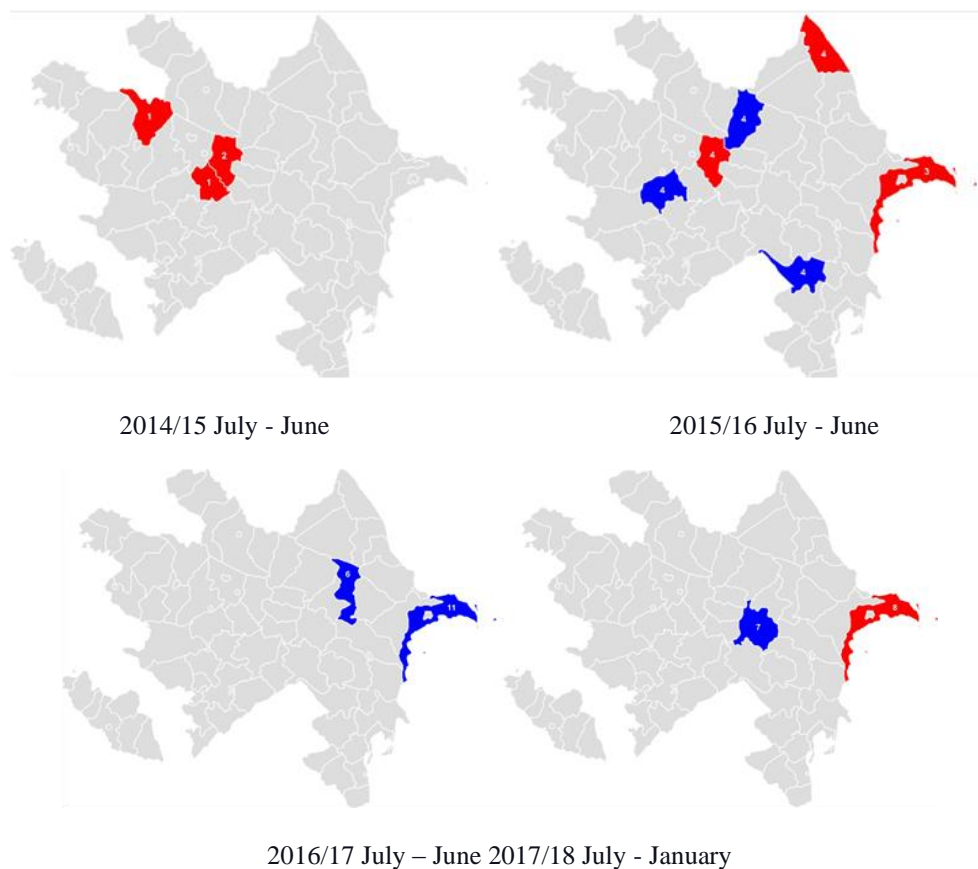


Figure 3. Spread of Schmallerberg disease in Azerbaijan (Zeynalova *et al.*, 2019).

The first wave of Schmallerberg virus infections was detected in 2012/2013 and limited mainly to the southern part of the country. In the second and bigger wave in 2013/2014, cases were found throughout most of the country (Zeynalova *et al.*, 2019).

Susceptible animals, transmission routes

It is proved that the transmission of *Bunyavirus* viruses is carried out by vectors. Most of these vectors live in Asia or Africa, which include biting midges or mosquitoes. After the appearance of the SBV virus in 2011, biting midges of the species *Culicoides Obsoletus* coming from the genus Ceratopogonid *Culicoides* were identified as SBV vectors. Studies have shown that the viral genome was present in different species of *Culicoides* (*Culicoides dewulfi*, *Culicoides chiopterus*, *Culicoides punctatus*, etc.) (Labuda, 1991; Rasmussen *et al.*, 2012).

The virus was isolated in the salivary glands of woodlice in Belgium. In laboratory conditions, virus RNAs were detected in biting midges *Culicoides Obseletus* collected in Denmark in 2011 (Davies & Daly, 2013; De Regge *et al.*, 2014; SVE, 2014). The absence of β -actin mRNA in ruminants and high titers of the virus in these samples indicate the replication of the virus in the insect organism, that is, *Culicoides punctatus* biting midges are biological carriers of the Schmallerberg disease virus (Figure 4) (Burgin *et al.*, 2013; EMS, 2014; Collins *et al.*, 2017).

Biting midges of the genus *Culicoides* are involved in the transmission of several viruses of the Simbu serogroup. They were recognized as the main carriers of Bluetongue virus in northern and central Europe during the outbreak in 2006 (White *et al.*, 2017; Nick, 2017; Rossel, 2018). Some members of the Simbu serogroup are zoonoses (Oropouche virus). Since the Schmallerberg virus has appeared recently, the transmission of the disease to humans has not yet been studied. There is no evidence of human morbidity, although studies conducted at the Dutch National Institute for Health and the Environment do not exclude the possibility of human infection with the Schmallerberg virus. At present, there are two ways of infection of animals: First is horizontal - with bites of blood-sucking insects of midges and mosquitoes. Second is vertically - from the mother to the fetus during fetal development (transplacental), accordingly in pregnant animals, infection leads to the birth of fetuses with congenital deformities (De Regge *et al.*, 2013; Lutikholt *et al.*, 2014; Afonso *et al.*, 2014; ProMED, 2014). The third route of infection should not be ruled out - iatrogenic, by veterinary specialists during veterinary prophylactic (vaccinations, chemotherapeutic treatments, subcutaneous, intramuscular injections, etc.) and diagnostic measures (taking blood, scrapings). However, no signs of horizontal transmission (from animal to animal) were found. Many questions remain regarding the pathogenesis of SBV infection in pregnant animals, their transmission by the embryo and / or gametes, and the dynamics of the virus to and within the fetus (Lehmann *et al.*, 2012; Hoffmann *et al.*, 2012; Briese *et al.*, 2013; Poskin *et al.*, 2014).



Figure 4. *Culicoides punctatus*

Clinical signs

Symptoms of the disease in cattle: in adult animals, fatigue, loss of appetite, fever, diarrhea, premature birth are first observed, part of the livestock die, milk yield decreases sharply, abortions occur in the last half of pregnancy and cases of stillbirths (Lievaart-Peterson *et al.*, 2012; Davies & Daly, 2013; Kauffold *et al.*, 2017). In sheep and goats, SBV infection remains subclinical. The nonspecific febrile syndrome was recorded in the summer and fall of 2011 in adult dairy cows in the Netherlands and Germany (Garigliany *et al.*, 2012; EFSA, 2014; White *et al.*, 2017). The disease is more severe in sheep and goats: there is a higher percentage of death, depletion of animals, damage to the reproductive organs in the maternal population. Sacral cleft of the spine was observed in two SBV-positive stillborn lambs in 2013 (De Regge *et al.*, 2013; Brülisauer *et al.*, 2017). In newborn animals, blindness, dropsy of the chest and abdominal cavities, paralysis, swelling in the subcutaneous tissue, and pathology of the lower jaw are noted. Such offspring, as a rule, die immediately after birth, the percentage of deaths varies from 20 to 50% in herds infected with the virus. An autopsy revealed common malformations of the central nervous system (CNS), including hydranencephaly, porencephaly, lissencephaly, hydrocephalus, cerebellar and cerebral hypoplasia, and micromyelia (Tsuda *et al.*, 2004; Hofmann *et al.*, 2012; Van den Brom *et al.*, 2012; Bilk *et al.*, 2012).



Figure 5. Clinical signs of Schmallenberg disease in the aborted fetuses

Laboratory diagnosis and prophylaxis of disease

Laboratory diagnostics

Diagnostics is carried out employing the PCR test (test - a system for determining the nucleic acid fragments of pathogens by polymerase chain reaction (PCR) in biological material). The test is extremely effective in identifying difficulties to cultivate cultures, pathogens that are not cultivated, latent forms of microorganisms in chronic and latent forms of infection. The use of PCR diagnostics is a highly effective method for determining intracellular parasites and viruses with high antigenic variability. The method can identify a pathogen fragment in the material from the animal, environmental objects (soil, water, etc.) (Lehmann *et al.*, 2012; Veronesi *et al.*, 2013). A significant drawback of this reaction is its high cost; the test takes a lot of time; it is carried out only in laboratory conditions with the appropriate equipment. DEFRA (UK Department of the Environment, Food, and Agriculture), as well as several institutes in Europe, are looking for a simple, easy-to-use, inexpensive test to determine the virus or its fragments. The virus itself was found in the intestinal contents of animals, the brain of sick and dead animals, blood samples, samples of intraperitoneal fluid, and blood-sucking insects (Rasmussen *et al.*, 2012; McGrath & More, 2018).

The first indirect enzyme-linked immunosorbent assay (ELISA) to detect Schmallenberg-specific antibodies in serum or milk samples became commercially available shortly after the emergence of SBV (Elbers *et al.*, 2012; Burgin *et al.*, 2013; Berhanu *et al.*, 2018). The most known kits are: the indirect ELISA kit for the detection of anti-Schmallenberg virus (SBV) antibodies in ruminant serum and plasma from multiple species, including cattle, sheep, and goats; competitive ELISA for the detection of antibodies directed against the Schmallenberg virus nucleoprotein in serum or plasma from multiple species (Humphries & Burr, 2012; Van der Poel *et al.*, 2014; Bréard *et al.*, 2013; Poskin *et al.*, 2015; Collins *et al.*, 2017).

Based on the available official data, the European Union does not consider vaccination mandatory during the spread of the disease. Currently, there is no information on the transmission of the virus with meat and milk and the vaccination against the virus is not required, however the ruminants that give birth to non-viable calves are considered as immunized. In the case of disease, the troupe of stillborn animals and afterbirth should be disposed of in accordance with local (national) regulations (EFSA, 2014; Zeynalova *et al.*, 2019).

So, despite some information, the Schmallenberg disease virus has not been sufficiently studied. It is still not clear how the virus occurs in Europe. The

evidence presented indicates that a lot of laboratory research and genetic tests are needed.

Abbreviations

SBV – Schmallenberg Virus

TSN- Animal Disease Reporting System

RNA- Ribonucleic acid

ELISA- Enzyme-linked Immunosorbent Assay

PCR- Polymerase chain reaction

DEFRA- Department for Environment, Food and Rural Affairs

References

- Afonso, A., Abrahantes, J.C., Conraths, F., Veldhuis, A., Elbers, A., Roberts, H., & et al.** (2014). The Schmallenberg virus epidemic in Europe—2011–2013. *Prev Vet Med.* 116:391–403.
- Bilk, S., Schulze, C., Fischer, M., Beer, M., Hlinak, A., & Hoffmann, B.** (2012). Organ distribution of Schmallenberg virus RNA in malformed newborns. *Vet Microbiol.* 159:236–8
- Bishop, D.H., & Beaty, B.J.** (1988). Molecular and biochemical studies of the evolution, infection, and transmission of insect bunyaviruses. *Philos. Trans. R. Soc. Lond. Series B Biol. Sci.* 321:463–483.
- Bréard, E., Lara, E., Comtet, L., & et al.** (2013). Validation of a commercially available indirect elisa using a nucleocapside recombinant protein for detection of Schmallenberg virus antibodies. *PLoS One.* 8(1): e53446.
- Briese, T., Calisher, C.H., & Higgs, S.** (2013). Viruses of the family Bunyaviridae: *Virology.* 446: 207–216.
- Charles, J.A.** (1994). Akabane virus. *Vet Clin North Am Food Anim Pract.* Nov. 10(3), 525-54.
- Berhanu, S., Gelagay, A., Endrias, Z.G., Eystein, S. & Kassahun, A.** (2018). Seroprevalence of Schmallenberg virus in dairy cattle in Ethiopia. *Acta Tropica.* 178: 61-67.
- Brülisauer, F., Scholes, S., Caldow, G.L., Rocchi, M., Dagleish, M.P., & Chianini, F.** (2017). Role of Schmallenberg virus infection in congenital malformations in ruminants in Scotland in spring 2017. *Vet Rec.* 181:341–3 British Medical Journal Publishing Group
- Burgin, L.E., Gloster, J., Sanders, C., Mellor, P.S., Gubbins, S., & Carpenter, S.** (2013). Investigating incursions of bluetongue virus using a model of longdistance *Culicoides* biting midge dispersal. *Transbound Emerg Dis.* 60(3):263–272.

- Collins, Á.B., Barrett, D.J., Doherty, M.L., McDonnell, M., & Mee, J.F.** (2017). Significant reemergence and recirculation of Schmallenberg virus in previously exposed dairy herds in Ireland in 2016. *Transbound Emerg Dis.* 64:1359–63.
- Collins, Á.B., Barrett, D., Doherty, M.L., Larska, M., & Mee, J.F.** (2017). Post-epidemic Schmallenberg virus circulation: parallel bovine serological and *Culicoides* virological surveillance studies in Ireland (2016). *BMC Vet Res* 12, 234.
- Conraths, F.J., Kamer, D., Teske, K., Hoffmann, B., Mettenleiter, T.C., & Beer, M.** (2013). Reemerging Schmallenberg virus infections, Germany, 2012. *Emerg Infect Dis.* 19(3):513–514.
- Coupeau, D., Claine, F., Wiggers, L., Kirschvink, N., & Muylkens, B.** (2013). In vivo and in vitro identification of a hypervariable region in Schmallenberg virus. *J Gen Virol.* 94(6):1168–1174.
- Davies, P., & Daly, J.** (2013). SBV transmission. *Vet Rec.* 172:509–10 British Medical Journal Publishing Group.
- De Regge, N., Madder, M., Deblauwe, I., & et al.** (2014). Schmallenberg virus circulation in *Culicoides* in Belgium in 2012: field validation of a real time RT-PCR approach to assess virus replication and dissemination in midges. *PLoS One.* 9(1): e87005
- De Regge, N., van den Berg, T., Georges, L., & Cay, B.** (2013). Diagnosis of Schmallenberg virus infection in malformed lambs and calves and first indications for virus clearance in the fetus. *Vet Microbiol.* 162(2–4):595–600.
- EFSA- European Food Safety Authority.** (2014). Schmallenberg virus: state of the art.
- EFSA.** (2014). Schmallenberg virus: State of art. *EFSA J.* 12(5): 3681.
- Elbers, A.R., Loeffen, W.L., Quak, S., & et al.** (2012). Seroprevalence of Schmallenberg virus antibodies among dairy cattle, the Netherlands, winter 2011–2012. *Emerg Infect Dis.* 18(7):1065–1071.
- Elbers, A.R., Koenraadt, C.J., & Meiswinkel, R.** (2015). Mosquitoes and *Culicoides* biting midges: vector range and the influence of climate change. *Rev Sci Tech.* 34(1):123–37.
- Elbers, A.R., Meiswinkel, R., van Weezep, E., Sloet, O. & et al.** (2011). Schmallenberg virus in *Culicoides* spp. biting midges, the Netherlands, 2011. *Emerg Infect Dis.* 19(1):106–109.
- Elliott, R.M.** (2009). Bunyaviruses and climate change. *Clin. Microbiol. Infect.* 15:510–517.
- EMS** - The emergence of Schmallenberg virus across *Culicoides* communities and ecosystems in Europe. 2014. *Prev Vet Med.* 116:360–9.
- Fischer, M., Schirrneier, H., Wernike, K., Wegelt, A., Beer, M., & Hoffmann, B.** (2013). Development of a pan-Simbu real-time reverse transcriptase PCR for the detection of Simbu serogroup viruses and comparison with SBV diagnostic PCR systems. *Virol J.* 10:327.
- Fischer, M., Hoffmann, B., Goller, K.V., Hoper, D., Wernike, K., & Beer, M.** (2013). A mutation ‘hot spot’ in the Schmallenberg virus M segment. *J Gen Virol.* 94 (6):1161–1167.

- Garigliany, M.M., Bayrou, C., Kleijnen, D., Cassart, D., & Desmecht, D.** (2012). Schmallenberg virus in domestic cattle, Belgium, 2012. *Emerg Infect Dis.* 18:1512–4
Centers for Disease Control and Prevention.
- Goller, K.V., Hoper, D., Schir, M.H, Mettenleiter, T.C., & Beer, M.** (2012). Schmallenberg virus as possible ancestor of Shamonda virus. *Emerg Infect Dis.* 18(10):1644–1646.
- Goller, K., & et al.** (2012). Schmallenberg disease in sheep or goats: Past, present, and future. *Vet Microbiol.* 181, 147-153.
- Gubbins, S., Richardson, J., Baylis, M., Wilson, A.J., & Abrahantes, J.C.** (2014). Modelling the continental-scale spread of Schmallenberg virus in Europe: Approaches and challenges. *Prev Vet Med.* 116, 404–411.
- Hoffmann, B., Scheuch, M., Höper, D., & et al.** (2012). Novel orthobunyavirus in cattle, Europe, 2011. *Emerg Infect Dis.* 18(3):469–472.
- Hofmann, B., Scheuch, M., & et al.** (2012). Schmallenberg disease in sheep or goats: Past, present and future. *Vet Microbiol.* 181, 147-153.
- Hofmann, B., Scheuch, M., Höper, D., Jungblut, R., Holsteg, M., Schirrmeyer, H., Eschbaumer, M., Humphries, D. & Burr, P.** (2012). Schmallenberg virus milk antibody ELISA. *Vet Rec.* 171(20):511–512.
- Horne, K.M., & Dana, L.** (2014). Vanlandingham, Bunyavirus-Vector Interactions. *Viruses.* 6(13): 4373-4397.
- ICTVI - International Committee on Taxonomy of Viruses Index of viruses-Bunyaviridae,** 2006.
- Kauffold, J., Vahlenkamp, T.W., Hoops, M.** (2017). Schmallenberg virus in Europe-a review.
- Kirkland, P.D.** (2015). Akabane virus infection. *Rev Sci Tech.* Aug; 34(2), 403-410.
- Labuda, M.** (1991). Arthropod vectors in the evolution of bunyaviruses. *Acta Virol.* 98–105.
- Lehmann, K., Werner, D., Hoffmann, B., & Kampen, H.** (2012). PCR identification of culicoid biting midges (Diptera, Ceratopogonidae) of the *Obsoletus* complex including putative vectors of bluetongue and Schmallenberg viruses. *Parasit Vectors.* 5:213.
- Lievaart-Peterson, K., Lutikholt, S.J.M., van den Brom, R., & Vellema, P.** (2012). Schmallenberg virus infection in small ruminants – First review of the situation and prospects in Northern Europe. *Small Rumin Res.* 106:71.
- Lutikholt, S., Veldhuis, A., van den Brom, R., & et al.** (2014). Risk factors for malformations and impact on reproductive performance and mortality rates of Schmallenberg virus in sheep flocks in the Netherlands. *PLoS One.* 9(6): e100135.
- Martinelle, L., Poskin, A., Dal Pozzo, F., Mostin, L., Van Campe, W., Cay, A.B., & et al.** (2017). Three different routes of inoculation for experimental infection with Schmallenberg virus in sheep. *Transbound Emerg Dis.* 64:305– 8.
- McGrath, G., & More, S.J.** (2018). O’Neill R. Hypothetical route of the introduction of Schmallenberg virus into Ireland using two complementary analyses. *Vet Rec* 182, 226–226.

- Nick, D.R.** (2017). Akabane, Aino and Schmallenberg virus- where do we stand and what do we know about the role of domestic ruminant hosts and culicoides vectors in virus transmission and overwintering. *Cur. Opin. Virol.*, 27: 15-30.
- Poskin, A., Martinelle, L., Mostin, L., & et al.** (2014). Dose-dependent effect of experimental Schmallenberg virus infection in sheep. *Vet J.* 201(3): 419–422.
- Poskin, A., Verite, S., Comtet, L., Van der Stede, Y., Cay, B., & De Regge, N.** (2015). Persistence of the protective immunity and kinetics of the isotype specific antibody response against the viral nucleocapsid protein after experimental Schmallenberg virus infection of sheep. *Vet Res.* 46:119 BioMed Central.
- ProMED-mail.** (2012). Schmallenberg virus – Europe (34): decline, update.
- ProMED-mail.** (2014). Schmallenberg virus – Europe (35): Netherlands, Germany, bovine.
- Rasmussen, L.D., Kristensen, B., Kirkeby, C., & et al.** (2012). Culicoids as vectors of Schmallenberg virus. *Emerg Infect Dis.* 18(7):1204–1206.
- Rossi, S., Viarouge, C., Faure, E., Gilot-Fromont, E., Gache, K., Gibert, P., Verheyden, H., Hars, J., Klein, F., Maillard, D., & et al.** (2015). Exposure of wildlife to the Schmallenberg virus in France (2011–2014): Higher, faster, stronger (than Bluetongue). *Transbound. Emerg. Dis.*, 64: 354-363.
- Roselkhoz nadzor/Epizootic Situation/Schmallenberg Disease. 2018
- Saeed, M.F., LiL., W.H., Weaver, S.C., & Barrett, A.D.** (2001). Phylogeny of the Simbu serogroup of the genus Bunyavirus. *J. Gen. Virol.* 82(21): 73-81.
- Sanders, C.J., Shortall, C.R., Gubbins, S., & et al.** (2011). Influence of season and meteorological parameters on flight activity of Culicoides biting midges. *J Appl Ecol.* 48(6):1355–1364.
- Scholte, E.J., Mars, M.H., Braks, M., & et al.** (2014). No evidence for the persistence of Schmallenberg virus in overwintering mosquitoes. *Med Vet Entomol.* 2014; 28:110–115.
- Stokes, J.E., Baylis, M., & Duncan, J.S.** (2015). Paper A freedom from disease study: Schmallenberg virus in the south of England.
- SVE-** Schmallenberg virus epidemic in Europe-2011-2013. (2014). *Prev Vet Med.* 116:391–403.
- Tarlington, R., Daly, J., Dunham, S. & Kydd, J.** (2012). Review-The challenge of Schmallenberg virus emergence in Europe. *Vet. J.* 194(1): 10-18.
- Tsuda, T., Yoshida, K., Ohashi, S., Yanase, T., Sueyoshi, M., Kamimura, S., Misumi, K., Hamana, K., Sakamoto, H., & Yamakawa, M.** (2004). Arthrogryposis, hydranencephaly and cerebellar hypoplasia syndrome in neonatal calves resulting from intrauterine infection with Aino virus. *Vet. Res.* 35: 531-538.
- Van den Brom, R., Luttkholt, S.J.M., Lievaart-Peterson, K., Peperkamp, N.H.M.T., Mars, M.H., van der Poel, W.H.M., & et al.** (2012). Epizootic of ovine congenital malformations associated with Schmallenberg virus infection. *Tijdschr Diergeneeskd.* 137:106–11.
- Van der Poel, W.H., Cay, B., Zientara, S., & et al.** (2014). Limited interlaboratory comparison of Schmallenberg virus antibody detection in serum samples. *Vet Rec.* 2014;174(15):380.

- Veronesi, E., Henstock, M., Gubbins, S., & et al.** (2013). Implicating *Culicoides* biting midges as vectors of Schmallerberg virus using semi-quantitative RT-PCR. *PLoS One*. 8 (3): 57747.
- Wernike, K., Silaghi, C., Nieder, M., Pfeffer, M. and Beer, M.** (2014). Dynamics of Schmallerberg virus infection within a cattle herd in Germany in 2011. *Epidemiol. Infect.* 142: 1501-1504.
- White, S.M., Sanders, C.J., Shortall, C.R., & Purse, B.V.** (2017). Mechanistic model for predicting the seasonal abundance of *Culicoides* biting midges and the impacts of insecticide control. *Parasit Vectors*. 10:162.
- Yanase, T., Kato, T., & Aizawa, M.** (2012). Genetic reassortment between Sathuperi and Shamonda viruses of the genus *Orthobunyavirus* in nature: implications for their genetic relationship to Schmallerberg virus. *Arch Virol*. 157(8):1611–1616.
- Zeynalova, Sh., & M.Vatani.** (2019). Schmallerberg virus in Azerbaijan 2012-2018, Springer, *Archives of Virology*, 164(7):1877-1881.