Anesthetic consideration for neuromuscular diseases

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Purpose of review
The aim of this review is to examine data relating to perioperative management of the patient with neuromuscular disorders

Recent findings
Patients with pre-existing neuromuscular disorders are at risk for a number of postoperative complications that are related to anesthetic drugs that are administered intraoperatively. Careful preoperative assessment is necessary to reduce morbidity and mortality. In particular, the risk of postoperative respiratory failure and need for long-term ventilation should be reviewed with patients. The use of succinylcholine should be avoided in muscular dystrophies, motor neuron diseases, and intrinsic muscle disease due to a risk of malignant hyperthermia, hyperkalemia, rhabdomyolysis, and cardiac arrest. The use of quantitative neuromuscular monitoring should be strongly considered whenever nondepolarizing neuromuscular blocking agents are administered. A number of case series and reports have been recently published demonstrating that sugammadex can be safely used in patients with neuromuscular disease; the risk of residual neuromuscular is nearly eliminated when this agent is administered intraoperatively.

Summary
Careful assessment and management of patients with underlying neuromuscular diseases is required to reduce postoperative complications. This article reviews the anesthetic implications of patients undergoing surgery with neuromuscular disorder.

Keywords
Duchenne muscular dystrophy, Lambert–Eaton myasthenic syndrome, myasthenia gravis, sugammadex

INTRODUCTION

Anesthesiologists must have an in-depth understanding of neuromuscular junction (NMJ) physiology as the medications used in daily practice have profound effects on neuromuscular transmission and muscle function [1]. Neuromuscular disease presents a complex challenge due to the susceptibility of the NMJ and muscle function to anesthetic medications. This review discusses disease physiology and recent experience with sugammadex.

GENERAL CONSIDERATIONS

Neuromuscular diseases present with a wide array of clinical manifestations, but important considerations remain consistent. Appreciating multisystem organ involvement and increased sensitivity to anesthetic medications is critical to perioperative management [2–5,6▪,7]. Outpatient medication regimens have important perioperative implications [8▪,9▪▪]. A comprehensive preoperative assessment may include consultation with neurology, cardiology, and pulmonary [5]. Work-up should include laboratory (Basic Metabolic Panel, Creatinine Kinase, myoglobin, Arterial blood gas), electrocardiogram, Chest Radiograph, echocardiogram, and Pulmonary Function Tests (PFTs) [10]. Disease-specific work-up will be discussed in the following sections and listed in Table 1.

A significant concern of the perioperative care of patients with neuromuscular disorders is the risk of postoperative respiratory failure [11]. Respiratory muscle weakness, poor cough and secretion management [12], bulbar dysfunction [9▪▪,13,14], cardiac involvement [7,15,16▪], and restrictive lung disease [17] contribute to respiratory failure. The use of neuromuscular blocking agents (NMBAs)

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Curr Opin Anesthesiol 2017, 30:435–440

DOI:10.1097/ACO.0000000000000466

KEY POINTS

- The use of succinylcholine should be avoided in muscular dystrophies, motor neuron diseases, and intrinsic muscle disease due to a risk of malignant hyperthermia, hyperkalemia, rhabdomyolysis, and cardiac arrest.
- The use of quantitative neuromuscular monitoring should be strongly considered whenever nondepolarizing neuromuscular blocking agents are administered.
- A number of case series and reports have been recently published demonstrating that sugammadex can be safely used in patients with neuromuscular disease; the risk of residual neuromuscular is eliminated when this agent is administered intraoperatively.

complicates the management, given the risk of residual blockade due to increased sensitivity (peak and duration) to nondepolarizing NMBAs [18,19]. Administration of succinylcholine must be avoided in muscular dystrophies, motor neuron diseases, and intrinsic muscle disease due to a risk of malignant hyperthermia, rhabdomyolysis, hyperkalemia, and cardiac arrest [3]. Reversal of NMB with sugammadex has been reported [20▪▪] in Duchenne muscular dystrophy (DMD) [21,22], Becker's muscular dystrophy (BMD) [23], and myasthenia gravis [24–28,29▪]. A case report exists showing the failure of sugammadex to completely reverse NMB [30]. Conventional NMB monitoring may lead to residual blockade [31,32▪▪,33]. Quantitative neuromuscular monitoring with careful titration of NMBAs should be considered [34,35,36▪▪]. Exclusion of NMBAs is often considered [37▪]. Postoperatively, anesthesiologists may consider ICU admission for monitoring and respiratory interventions [38▪,39▪,40]. Disease-specific anesthesia considerations are discussed in the following sections and in Table 2.

DUCHENNE MUSCULAR DYSTROPHY

Duchenne muscular dystrophy is a X-linked disease of the dystrophin gene that disrupts the sarcolemmal integrity, affecting 1/3500 [41]. Muscle weakness develops early in childhood and average lifespan is 30 years from cardiomyopathy or respiratory failure [6▪,42–45]. Scoliosis is common and causes restrictive lung disease [46]. Corticosteroids are a mainstay of therapy, but do not effect cardiac manifestations [47▪▪]. Standard heart failure medical management is used for DMD; Left Ventricular Assist Devices implantation for destination therapy has been described [48,49].

Perioperative management of DMD patients is difficult [50]. Preoperative determination of cardiopulmonary reserve is paramount with PFTs, electrocardiogram, and echocardiogram/cardiac MRI

Table 1. Diseases (pathophysiology and recommended work-up) [3,4,10]

Disease	Pathophysiology	Clinical issues	Therapeutics	Preop work-up
Duchenne and Becker	Dystrophin gene mutation; X-linked	Weakness Chronic respiratory failure Cardiomyopathy	Corticosteroids Scoliosis correction Supportive	Cardiac w/echo or MRI PFTs
Myasthenia gravis	Postsynaptic ACh-receptor antibody	Weakness Muscle fatigue with use Occular muscles always involved Thymoma	AChesterase inhibitors Immunesuppression Steroids Azathioprine Rituximab Mycophenolate Cyclosporine Methotrexate Acute exacerbations IVIg Plasma exchange	PFTs Review chest imaging if available for anterior mediastinal mass
Lambert–Eaton	Presynaptic calcium channel antibody	Weakness Facilitation ~50% have small cell lung cancer	3,4-diaminopyridine Oncologic treatment	PFTs Review chest imaging
Guillain–Barre	Autoimmune demylination of peripheral nerves	Begins in lower extremities and progresses cephalad Often occurs after viral syndrome (i.e. URI) Respiratory failure Autonomic dysfunction	Plasma exchange IVIg Supportive care Rehabilitation Pain control	PFTs as indicated Possible association to neuroaxial anesthesia

Table 2. Diseases (anesthetic consideration) [3,4,10]

Disease	Volatile agents	Succinylcholine	Nondepolarizers	Regional anesthesia
Duchenne and Becker	No	No	Decreased dose	Yes
Myasthenia gravis	Yes	Yes, resistance	Decrease dose	Yes
Lambert–Eaton	Yes	Decrease dose	Decrease dose	Yes
Guillain–Barre	Yes	No	Decrease dose	Yes

[5,17,51▪,52]. A forced vital capacity less than 30% suggests higher respiratory complication rate [53], but spinal surgery has been successful in this setting [20▪▪]. DMD is associated with delayed gastric emptying. Scoliosis may make airway management difficult [4]. Succinylcholine is contraindicated secondary to the risk of hyperkalemia, rhabdomyolysis, and cardiac arrest; rapid sequence induction with rocuronium has been reported [25]. Volatile anesthetics are associated with anesthesia-induced rhabdomyolysis (AIR), hyperkalemia, and cardiac arrest [54–57]. AIR is often confused for malignant hyperthermia and is treated the same [58,59]. TIVA is the preferred method of general anesthesia [5]. Sugammadex has been used successfully [25]. Sedation and regional anesthesia are well tolerated in DMD [60▪,61,62]. ICU admission and postoperative intubation may be required [63–65].

BECKER'S MUSCULAR DYSTROPHY

Similar to DMD, BMD is an X-linked recessive disorder of the dystrophin gene. It is less severe and later presentation than DMD [66]. It affects 1 in 18 450 and patients are wheelchair bound by age 16 [67▪]. Cardiopulmonary dysfunction is common [68▪]. Anesthetic considerations and management are similar to DMD [27,69].

MYASTHENIA GRAVIS

Myasthenia gravis is a neuromuscular disorder caused by antibodies to the postsynaptic acetylecholine receptors at the NMJ, resulting in weakness [70]. The prevalence is 1.5–2.5 per 10 000 [71]. Weakness can be localized (bulbar) or generalized, worsens with repetition, and eye muscles are affected [72]. Diagnosis is clinical and antibody detection is confirmatory, but there are also seronegative patients [73,74]. Outpatient therapy includes acetylcholinesterase inhibitors and immunosuppression. Thymectomy is common for patients both with and without thymoma [75]. Myasthenia during pregnancy has an unpredictable course and can complicate labor, delivery, and newborn well being [76,77]. Life-threatening exacerbations are treated with immunoglobulin and plasma exchange [9▪▪].

Perioperative management of myasthenia gravis is challenging. Emphasis is placed on NMB management and possible postoperative ventilation [78▪]. Disease severity and respiratory/bulbar compromise should be documented. PFTs should be performed and thymomas are anterior mediastinal masses [79▪]. Postoperative ventilation is more likely in patients with preoperative respiratory/bulbar dysfunction and Osserman disease severity scale III or IV (Table 3) [80,81].

Intraoperative general anesthesia has been successful with multiple modalities including inhalational, TIVA, and combined general-epidural [82–88]. The neuromuscular blocking effects of volatile anesthetics is exaggerated in myasthenia gravis [12,89,90]. Avoidance of NMBAs is a common strategy. If used, careful titration and monitoring of NMBAs is mandatory; quantitative monitoring should also be considered [91]. Patients exhibit a higher threshold to succinylcholine, but are susceptible to a phase II block [92]. Sugammadex has been used successfully in myasthenia gravis and should be considered [29▪]. Regional and local anesthesia have been used successfully. Postoperative ventilation should be considered if patients exhibit signs of weakness. Weakness postoperatively may be myasthenic crisis, residual anesthesia, residual NMBAs, or other perioperative medications that can exacerbate muscle weakness (i.e. gentamicin). Cholingeric crisis is possible with anticholinesterase medications [4]. ICU monitoring may be required.

Table 3. Myasthenia gravis Osserman disease severity score

Grade 1	Focal disease (ocular symptoms only)
Grade 2a	Mild generalized disease, prominent limb involvement
Grade 2b	Moderate generalized disease, bulbar prominence
Grade 3	Acute severe disease with respiratory symptoms
Grade 4	Severe generalized disease with respiratory symptoms

Data from [81].

LAMBERT–EATON MYASTHENIC SYNDROME

Lambert–Eaton myasthenic syndrome (LEMS) is an autoimmune disease of the NMJ from antibodies to the presynaptic calcium channel; half are related to small cell lung cancer [1]. Weakness tends to affect proximal limb muscles, but bulbar muscles are often spared; respiratory and autonomic dysfunction are common [16▪]. Electromyograms and autoantibodies aid in the diagnosis [1]. Facilitation (improvement in strength with repetition) is common. Treatment is aimed at the underlying tumor and with 3,4-diaminopyridine [93▪].

Perioperative management is similar to myasthenia gravis; however, LEMS patients are sensitive to all NMBAs [94]. Association with bronchogenic carcinoma and airway obstruction may be a concern.

CONCLUSION

Careful preoperative assessment is necessary to avoid complications in patients with neuromuscular disorders. Anesthesia can impact postoperative muscle weakness in this population. Choice of NMBAs and reversal agents is essential. Early data support the use of sugammadex.

Acknowledgements

None.

Financial support and sponsorship

None.

Conflicts of interest

J.K.: None; G.S.M.: Speaker and advisor for Merck.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

- ▪ of special interest
- ▪▪ of outstanding interest

1. Hirsch NP. Neuromuscular junction in health and disease. Br J Anaesth 2007; 99:132–138.
2. Drissen JJ. Neuromuscular and mitochondrial disorders: what is relevant to the anaesthesiologist? Curr Opin Anesthesiol 2008; 21: 350–355.
3. Racca F, Mongini T, Wolfler A, *et al.* Recommendations for anesthesia and perioperative management of patients with neuromuscular disorders. Minerva Anesthesiol 2013; 79:419–433.
4. Book WJ, Abel M, Eisenkraft JB. Anesthesia and neuromuscular diseases. Anesth Clin N Am 1996; 14:515–542.
5. Birnkrant DJ. The American College of Chest Physicians Consensus Statement on the respiratory and related management of patients with Duchenne muscular dystrophy undergoing anesthesia or sedation. Pediatrics 2009; 123:S242–S244.
6. ▪ Posner AD, Soslow JH, Burnette WB, *et al.* The correlation of skeletal and cardiac muscle dysfunction in Duchenne muscular dystrophy. J Neuromusc Dis 2016; 3:91–99.

This article suggests that cardiac function decline may actually mirror the decline in skeletal muscle dysfunction.

7. Brunklaus A, Parish E, Muntoni F, *et al.* The value of cardiac MRI versus echocardiography in the pre-operative assessment of patients with Duchenne muscular dystrophy. Eur J Paedtr Neurol 2015; 19:395–401.
8. ▪ Vry J, Gramsch K, Rodger S, *et al.* European cross-sectional survey of current care practices for Duchenne muscular dystrophy reveals regional and age-dependent differences. J Neuromusc Dis 2016; 3:517–527.

Cross-sectional survey on how patients with DMD are treated.

9. ▪▪ Gilhus NE. Myasthenia gravis. N Engl J Med 2016; 375:2570–2581.

Comprehensive review on the current state of science in myasthenia gravis in terms of epidemiologist, diagnosis, subtypes, and treatment.

10. Klingler W, Lehmann-Horn F, Jurkat-Rott K. Complications of anaesthesia in neuromuscular disorders. Neuromusc Disord 2015; 15:195–206.
11. Dillon FX. Anesthesia issues in the perioperative management of myasthenia gravis. Semin Neurol 2004; 24:83–94.
12. Kravitz RM. Airway clearance in Duchenne muscular dystrophy. Pediatrics 2009; 123:S231–S235.
13. Hülsbrink R, Hashemolhosseini S. Lambert–Eaton myasthenic syndrome: diagnosis, pathogenesis and therapy. Clin Neurophysiol 2014; 125:2328–2336.
14. Titulaer MJ, Lang B, Verschuuren JJ. Lambert–Eaton myasthenic syndrome: from clinical characteristics to therapeutic strategies. Lancet Neurol 2011; 10:1098–1107.
15. Cripe LH, Tobias JD. Cardiac considerations in the operative management of the patient with Duchenne or Becker muscular dystrophy. Pediatr Anesth 2013; 23:777–784.
16. ▪ Finasterer J, Stöllberger C. Heart disease in disorders of muscle, neuromuscular transmission, and the nerves. Kor Circ J 2016; 46:117–118.

Review of heart disease in neuromuscular disorders.

17. Harper CM, Ambler G, Edge G. The prognostic value of pre-operative predicted forced vital capacity in corrective spinal surgery for Duchenne's muscular dystrophy. Anaesthsia 2004; 54:1160–1162.
18. Eisenkraft JB, Book WJ, Papatestas AE. Sensitivity to vecuronium in myasthenia gravis: a dose-response study. Can J Anesth 1990; 37:301–306.
19. Muenster T, Schmidt J, Wick S, *et al.* Rocuronium 0.3 mg.kg^{-1} (ED95) induces a normal peak effect but an altered time course of neuromuscular block in patients with Duchenne's muscular dystrophy. Pediatr Anesth 2006; 16:840–845.
20. ▪▪ Tobias JD. Current evidence for the use of sugammadex in children. Pediatr Anesth 2016; 27:118–125.

Broad review on the use of sugammadex in children. Includes neuromuscular disorders, but is more broadly focused.

21. de Boer HD, Esmond JV, Booij LH, dDriessen JJ. Reversal of rocuronium-induced profound neuromuscular block by sugammadex in Duchenne muscular dystrophy. Pediatr Anesth 2009; 19:1226–1228.
22. Shousha AA, Sanfilippo M, Sabba A, Pinchera P. Case report sugammadex and reversal of neuromuscular block in adult patient with Duchenne muscular dystrophy. Case Rep Anesthesiol 2014; 2014:680568.
23. Shimauchi T, Yamaura K, Sugibe S, Hoka S. Usefulness of sugammadex in a patient with Becker muscular dystrophy and dilated cardiomyopathy. Acta Anaesthesiol Taiwan 2014; 52:146–148.
24. de Boer HD, Egmond JV, Driessen JJ, Booji LH. Sugammadex in patients with myasthenia gravis. Anaesthesia 2010; 65:653.
25. Unterbuchner C, Fink H, Blobner M. The use of sugammadex in a patient with myasthenia gravis. Anaesthesia 2010; 65:302–305.
26. Jakubia J, Gaszynski T, Gaszynski W. Neuromuscular block reversal with sugammadex in a morbidly obese patient with myasthenia gravis. Anaesthesiol Intensive Ther 2012; 44:28–30.
27. Ulke ZS, Yavru A, Camci E, *et al.* Rocuronium and Sugammadex in patients with myasthenia gravis undergoing thymectomy. Acta Anaesthesiol Scand 2013; 57:745–748.
28. Vymazal T, Krecmerova M, Bicek V, Lischke R. Feasibility of full and rapid neuromuscular blockade recovery with Sugammadex in myasthenia gravis patients undergoing surgery; series of 117 cases. Therapeut Clin Risk Manag 2015; 11:1593–1596.
29. ▪ Sungur Z, Sentürk M. Anaesthesia for thymectomy in adult and juvenile myasthenic patients. Curr Opin Anaesthesiol 2016; 29 (1):14–19.

Review of anesthesia for thymectomy with the use of sugammadex.

30. Ortiz-Gómez JR, Palacio-Abizanda FJ, Fornet-Ruiz I. Failure of Sugammadex to reverse rocuronium-induced neuromuscular blockade. Eur J Anaesthesiol 2014; 31:708–709.
31. Fortier LP, McKeen D, Turner K, *et al.* The RECITE study: a Canadian prospective, multicenter study of the incidence and severity of residual neuromuscular blockade. Anesth Analg 2015; 121:366–372.
32. ▪▪ Batistaki C, Tentes P, Deligiannidi P, *et al.* Residual neuromuscular blockade in a real life clinical setting: correlation with sugammadex or neostigmine administration. Minvera Anestesiol 2016; 82:550–558.

Broad review on differences between sugammadex and neostigmine.

33. Murphy GS, Szokol JW, Marymont JH, *et al.* Residual neuromuscular blockade and critical respiratory events in the postanesthesia care unit. Anesth Analg 2008; 107:130–137.
34. Fujimoto M, Terasaki S, Nishi M, Yamamoto T. Response to rocuronium and its determinants in patients with myasthenia gravis. Eur J Anaesthesiol 2015; 32:672–680.

35. Murphy GS, Szokol JW, Marymont JH, *et al.* Intraoperative acceleromyographic monitoring reduces the risk of residual neuromuscular blockade and adverse respiratory events in the postanesthesia care unit. Anesthesiol 2008; 109:389–398.

36. ■■ Thilen SR, Bhananker SM. Qualitative neuromuscular monitoring: how to optimize the use of a peripheral nerve stimulator to reduce the risk of residual neuromuscular blockade. Curr Anesth Report 2016; 6:164–169.

Questions the normative practice of qualitative neuromuscular blockade monitoring and discusses how to use qualitative monitoring.

37. ■ Akatsu M, Ikegami Y, Tase C, Nishikawa K. Anesthetic management of a patient with antimuscle-specific kinase antibody-positive myasthenia gravis undergoing an open cholecystectomy. A A Case Rep 2017; 1–4.

Case report of a patient with myasthenia undergoing combined general-epidural anesthesia for an open abdominal surgery using quantitative neuromuscular monitoring.

38. ■ Marinho A, Guimaraes MJ, Lages NC, Correia C. Role of noninvasive ventilation in perioperative patients with neuromuscular disease: a clinical case. Braz J Anesthesiol 2017; 66:72–74.

Case report of the use of noninvasive ventilation and chest physiotherapy in caring for a patient with neuromuscular disease.

39. ■ Vianello A, Arcaro G, Braccioni F. Preventive non-invasive ventilation is indicated for neuromuscular disease patients after extubation. Minverva Anestesiol 2012; 78:390.

Randomized controlled trial of noninvasive ventilation and chest physiotherapy in neuromuscular disease. Lowers re-intubation rate, no change in mortaility.

40. Vianello A, Arcaro G, Braccioni F, *et al.* Prevention of extubation failure in high-risk patients with neuromuscular disease. J Crit Care 2011; 26:517–524.

41. Khurana TS, Davies KE. Pharmacological strategies for muscular dystrophy. Nature Rev Drug Discov 2003; 2:379–390.

42. Towbin JA. Inherited cardiomyopathies. Circulation 2014; 78:2347–2356.

43. Rajdev A, Groh WJ. Arrhythmias in the muscular dystrophies. Cardiovasc Electrophysiol Clin 2015; 7:303–308.

44. Fayssoil A, Nardi O, Orlikowski D, Annane D. Cardiomyopathy in Duchenne muscular dystrophy: pathogenesis and therapeutics. Heart Fail Rev 2010; 15:103–107.

45. Segura LG, Lorenz JD, Weingarten TN, *et al.* Anesthesia and Duchenne or Becker muscular dystrophy: review of 117 anesthetic exposures. Pediatr Anesth 2013; 23:855–864.

46. Ames WA, Hayes JA, Crawford MW. The role of corticosteroids in Duchenne muscular dystrophy: a review for the anesthetist. Pediatr Anesth 2005; 15:3–8.

47. ■■ Matthews E, Brassington R, Kuntzer T, *et al.* Corticosteroids for the treatment of Duchenne muscular dystrophy. Cochrane Database Syst Rev 2016; 5.

Cochrane quality evidence for the treatment of DMD.

48. Iodice F, Testa G, Averardi M, *et al.* Implantation of a left ventricular assist device as a destination therapy in Duchenne muscular dystrophy patients with end stage cardiac failure: management and lessons learned. Neuromusc Disord 2015; 25:19–23.

49. Ryan TD, Jefferies JL, Sawnani H, *et al.* Implantation of the HeartMate II and HeartWare left ventricular assist devices in patients with Duchenne muscular dystrophy. ASAIO J 2014; 60:246–248.

50. Hopkins PM. Anaesthesia and the sex-linked dystrophies: between a rock and a hard place. Brit J Anaesth 2010; 104:397–400.

51. ■ Soslow JH, Xu M, Slaughter JC, *et al.* Evaluation of echocardiographic measures of left ventricular function in patients with Duchenne muscular dystrophy: assessment of reproducibility and comparison to cardiac magnetic resonance imaging. J Am Soc Echocardiogr 2016; 29:983–991.

Cardiac MRI is noninferior for preoperative work-up when compared to echocardiography.

52. Lang SM, Shugh S, Mazur W, *et al.* Myocardial fibrosis and left ventricular dysfunction in Duchenne muscular dystrophy carriers using cardiac magnetic resonance imaging. Pediatr Cardiol 2015; 36:1495–1501.

53. Milne B, Rosales JK. Anaesthetic considerations in patients with muscular dystrophy undergoing spinal fusion and Harrington rod insertion. Can Anaesth 1982; 29:250–255.

54. Yemen TA, McClain C. Muscular dystrophy, anesthesia and the safety of inhalational agents revisited: again. Pediatr Anesth 2006; 16:105–108.

55. Girshin M, Mukherjee J, Clowney R, *et al.* The postoperative cardiovascular arrest of a 5-year-old male: an initial presentation of Duchenne's muscular dystrophy. Pediatr Anesth 2006; 16:170–173.

56. Obata R, Yasumi Y, Suzuki A, *et al.* Clinical reports rhabdomyolysis in association with Duchenne's muscular dystrophy. Can J Anesth 1990; 46:564–566.

57. Hayes J, Veyckemans F, Bissonnette B. Rhabdomyolysis and anesthesia. Pediatr Anesth 2008; 8:897–899.

58. Hayes J, Veyckemans F, Bissonnette B. Duchenne muscular dystrophy: an old anesthesia problem revisited. Pediatr Anesth 2007; 18:100–106.

59. Gurnaney H, Brown A, Litman RS. Malignant hyperthermia and muscular dystrophies. Anesth Analg 2009; 109:1043–1048.

60. ■ Bang SU, Kim YS, Kwon WJ, *et al.* Peripheral nerve blocks as the sole anesthetic technique in a patient with severe Duchenne muscular dystrophy. J Anesth 2016; 30:320–323.

Case report describing peripheral nerve block in DMD.

61. Kako H, Corridore M, Kean J, *et al.* Dexmedetomidine and ketamine sedation for muscle biopsies in patients with Duchenne muscular dystrophy. Pediatr Anesth 2014; 24:851–856.

62. Büget Mİ, Eren İ, Küçükay S. Regional anaesthesia in a Duchenne muscular dystrophy patient for upper extremity amputation. J Turkish Soc Algol 2014; 26:191–195.

63. Muenster T, Mueller C, Forst J, *et al.* Anaesthetic management in patients with Duchenne muscular dystrophy undergoing orthopaedic surgery. Eur J Anaesthesiol 2012; 29:489–494.

64. Miles F, Dare T. Scoliosis repair in a teenager with Duchenne's muscular dystrophy: who calls the shots? Pediatr Anesth 2009; 19:1022–1024.

65. E Caliskan E. Duchenne muscular dystrophy: how I do it? Regional or general anesthesia? Pediatr Anesth 2009; 19:624.

66. Rumeur EL. Dystrophin and the two related genetic diseases, Duchenne and Becker muscular dystrophies. Bosnian J Basic Med Sci 2015; 15:14–20.

67. ■ Barakat-Haddad C, Shin S, Candundo H, *et al.* A systematic review of risk factors associated with muscular dystrophies. Neurotoxicology 2016; 1–8.

Review article discussing genetic and other risk factors associated with muscular dystrophies.

68. ■ Ho R, Nguyen M, Mather P. Cardiomyopathy in Becker muscular dystrophy: overview. World J Cardiol 2016; 8:356–361.

Review article discussing heart disease in patients with BMD.

69. Poole TC, Lim TYJ, Buck J, Kong AS. Perioperative cardiac arrest in a patient with previously undiagnosed Becker's muscular dystrophy after isoflurane anaesthesia for elective surgery. Brit J Anaesth 2010; 104:487–489.

70. Baraka A. Anesthesia and critical care of thymectomy for myasthenia gravis. Chest Surg Clin N Am 2001; 11:337–361.

71. Carr AS, Cardwell CR, McCarron PO, McConville J. A systematic review of population based epidemiological studies in myasthenia gravis. BMC Neurol 2010; 10:475–479.

72. Gilhus NE, Verschuuren JJ. Myasthenia gravis: subgroup classification and therapeutic strategies. Lancet Neurol 2015; 14:1023–1036.

73. Zisimopoulou P, Brenner T, Trakas N, Tzartos SJ. Serological diagnostics in myasthenia gravis based on novel assays and recently identified antigens. Autoimmun Rev 2013; 12:924–930.

74. Reddel SW, Morsch M, Phillips WD. Clinical and scientific aspects of muscle-specific tyrosine kinase-related myasthenia gravis. Curr Opin Neurol 2014; 27:558–565.

75. Fujita Y, Moriyama S, Aoki S, *et al.* Estimation of the success rate of anesthetic management for thymectomy in patients with myasthenia gravis treated without muscle relaxants: a retrospective observational cohort study. J Anesth 2015; 29:794–797.

76. Almeida C, Coutinho E, Moreira D, *et al.* Myasthenia gravis and pregnancy: anaesthetic management: a series of cases. Eur J Anaesth 2010; 27:985–990.

77. Djeimis J, Sostarko M, Mayer D, *et al.* Myasthenia gravis in pregnancy: report on 69 cases. Eur J Ob Gyn Reprod Biol 2002; 104:21–25.

78. ■ Ozel F, Altunkan AA, Azizoglu M. Postoperative respiratory failure in a patient with undiagnosed myastenia gravis. Turkish J Anesth Reanim 2016; 44:108–110.

Case report of a patient being diagnosed with myasthenia after postoperative respiratory failure.

79. ■ Sungur Z, Sentürk M. Anaesthesia for thymectomy in adult and juvenile myasthenic patients. Curr Opin Anaesthesiol 2016; 29:14–19.

Review of anesthesia for thymectomy with the use of sugammadex.

80. Lu W, Yu T, Longhini F, *et al.* Preoperative risk factors for prolonged postoperative ventilation following thymectomy in myasthenia gravis. Int J Clin Exp Med 2015; 8:13990–13996.

81. Mao Z, Hu X, Lu Z, Hackett ML. Prognostic factors of remission in myasthenia gravis after thymectomy. Eur J Cardiothorac Surg 2016; 48:18–24.

82. Liu XZ, Wei CW, Wang HY, *et al.* Effects of general-epidural anaesthesia on the hemodynamics in patients with myasthenia gravis. West Ind Med J 2015; 64:99–103.

83. Leuzzi G, Meacci E, Cusumano G, *et al.* Thymectomy in myasthenia gravis: proposal for a predictive score of postoperative myasthenic crisis. Eur J Cardiothorac Surg 2014; 45:e76–e88.

84. Sonzogni R, Novellino L, Benigni A, *et al.* Video-assisted thoracoscopic extended thymectomy in myasthenic children. Pediatr Rep 2013; 5:17–19.

85. Gritti P, Sgarzi M, Carrara B, *et al.* A standardized protocol for the perioperative management of myasthenia gravis patients. Experience with 110 patients. Acta Anaesthesiol Scand 2011; 56:66–75.

86. Gritti P, Carrara B, Khotcholava M, *et al.* The use of desflurane or propofol in combination with remifentanil in myasthenic patients undergoing a video-assisted thoracoscopic-extended thymectomy. Acta Anaesthesiol Scand 2009; 53:380–389.

87. Rocca GD, Coccia C, Diana L, *et al.* Propofol or sevoflurane anesthesia without muscle relaxants allow the early extubation of myasthenic patients. Gen Anesth 2008; 50:547–552.

88. Kowalczyk M, Nestorowicz A, Stachurska K, *et al.* Myasthenia gravis: a careful perioperative anesthetic management of coronary artery bypass grafting. J Neurosci Nurs 2015; 47:161–165.

89. Blichfeldt-Lauridsen L, Hansen BD. Anesthesia and myasthenia gravis. Acta Anaesth Scand 2011; 56:17–22.

90. Nitahara K, Sugi Y, Higa K, *et al.* Neuromuscular effects of sevoflurane in myasthenia gravis patients. Brit J Anaesth 2007; 98:337–341.
91. de Boer HD, Fuchs-Duder T. Residual neuromuscular blockade and myasthenia gravis. Acta Anaesthesiol Scand 2012; 56: 932–933.
92. Eisenkraft JB, Book WJ, Mann SM, *et al.* Resistance to succinylcholine in myasthenia gravis. Anesthesiol 1988; 69:760–763.
93. Abenroth DC, Sith AG, Greelee JE, *et al.* Lambert-Eaton myasthenic syndrome ■ (LEMS): epidemiology and therapeutic response in the National Veterans Affairs (VA) population. Muscle Nerve 2016; 20:. [Epub ahead of print]
Treatment and prevalence of LEMS is discussed in this article.
94. Weingarten TN, Araka CN, Mogensen ME, *et al.* Lambert-Eaton myasthenic syndrome during anesthesia: a report of 37 patients. J Clin Anesth 2014; 26:648–653.