TOTAL INTRAVENOUS ANESTHESIA VERSUS TOTAL INTRAVENOUS ANESTHESIA WITH PARTIAL NEUROMUSCLAR BLOCKADE ON NEUROPHYSIOLOGICAL MONITORING IN ADOLESCENT IDIOPATHIC SCOLIOSIS CORRECTIVE SURGERY

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Abstract

Background: The intraoperative neurophysiological monitoring (IONM) is used now to decrease the incidence of complications during spinal surgeries. This study was done to detect the effect of adding partial muscle relaxant to total intravenous anesthesia (propofol – dexmedetomidine – fentanyl) on neurophysiological monitoring in adolescent idiopathic scoliosis corrective surgery.

Aim: detection of the best anesthetic technique regarding IONM to minimize iatrogenic neurological complications during scoliosis surgery.

Patients and Methods: This randomized clinical trial study was conducted on 36 patients presenting with scoliosis admitted to Zagazig university hospitals for spinal correction surgery. The studied patients were divided into two groups. Group T (TIVA only group) (n=18): Patients received TIVA including propofol, dexmedetomidine and fentanyl . Group M (TIVA with partial muscle blockade group) (n= 18): Patients received TIVA including propofol and dexmedetomidine plus small dose of rocuronium (0.6 mg/kg/h). Neurophysiological monitoring mainly included Motor evoked potentials and somatosensory evoked potential. **Results:** Regarding MEPs amplitude ,it was significantly higher in group T at different follow up periods .Regarding SSEPs amplitude ,there is no significant difference between both groups .Regarding SSEPs latency ,there was no significant difference between both groups. Regarding Train of Four (TOF) at different follow-up periods, the current study showed that TOF was significantly lower in group M compared to group T at different follow up times. Although using rocuronium, and when TOF's count was 2-3 ,this didn't affect our neurophysiological monitoring, Depth of anesthesia by spectral edge frequency (SEF) was significantly different between both groups as it was lower in group M rather than group T, Regarding surgeon satisfaction ,In group M the majority of surgeons showed excellent response (72.2%) but in group T the majority of them showed good response (66.7%). Regarding recovery characteristics time to eye opening , time to follow commands and time of tracheal extubation were lower in Group M specially after usage of sugammadex for reversal of rocuronium so no fear for delayed recovery from muscle relaxant or residual effect of continuous use of rocuronium.

Conclusion: the current study showed that infusion of small dose of muscle relaxant (rocuronium) effectively inhibit the involuntary movement and facilitate tracheal extubation without disturbing the motor or sensory evoked potential variability. Additionally, better recovery characteristics, lower blood loss, higher surgeon satisfaction and favorable depth of anesthesia was found in partial neuromuscular blockade.

Keywords: Neuromuscular Blockade, Total Intravenous Anesthesia, Propofol Dexmedetomidine Fentany, Neurophysiological Monitoring, Adolescent Idiopathic Scoliosis corrective Surgery

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Introduction

Adolescent idiopathic scoliosis (AIS) is a type of scoliosis with 3- dimensional anatomical deformity of the spine, including variations in alignment of the sagittal plane, deviations in coronal plane, and vertebral rotation in axial plane in the absence of congenital or neuromuscular abnormalities .It affects adolescent 10 to 18 years and it is the commonest type among other types of scoliosis .The incidence is similar between males and females. However, females are 10 times more likely to progress to Cobb angles of 30 degrees or more **(1)**.

The IONM is used now to decrease the incidence of the complications during spine surgeries by avoiding direct and indirect injuries of the spinal cord **(2)**. IONM includes :(somatosensory evoked potentials (SSEPs) to monitor the integrity of the dorsal column of the spinal cord as an electrical or magnetic impulse is delivered to the periphery producing electric potentials that propagate through

the spinal cord to the brain, motor evoked potentials (MEPs) to monitor the integrity of the anteriorly located motor tracts of the spinal cord as an electrical or magnetic impulse is delivered to the brain or spinal cord proximal to the surgical site).There are challenges to the anesthesiologist during IONM because all anesthetic agents and neuromuscular agents affect synapses in the nervous system and neuromuscular junctions. This effect differs from the use of one modality to another and from one anesthetic agent to another **(3)**.

Neuromuscular blocking agents (NMBA) are commonly used in anesthesiology to improve conditions for endotracheal intubation, mechanical ventilation, and for relaxation of muscles necessary for the conduct of the surgical procedure. However, their use during IONM are controversial because they can reduce the amplitude of the responses and simulate loss of neural function; many individuals recommend their avoidance during the monitoring portion of procedures. However a variety of studies and clinical experience revealed that partial muscle blockade is compatable with neuromonitoring **(4)**.

Rocuronium is a muscle relaxant with increased use, because of the binding relation with the reversal agent sugammadex. Its continuous infusion benefits the maintenance of deeper levels of neuromuscular blockade (NMB) ensuring an improved and stable solution for daily surgical anesthesia. It is characterized by quick onset action, dose-based duration, no secondary effects known, no active metabolites nor toxins, and hepatic elimination (**5)**.

Our aim in this study was detection of the best anesthetic modality regarding IONM to minimize iatrogenic neurological complications during scoliosis corrective surgery.

Patients and Methods

After obtaining approval from the scientific committee of anesthesia and surgical intensive care department and institutional review board (IRB) of faculty of medicine and a written informed consent from all the parents or guardian after explaining to them the nature of the study , this prospective randomized comparative double blind (in which both the anesthesiologist and neurophysiologist weren't oriented about the anesthetic technique) clinical trial was carried out at Zagazig university hospitals over 2 years from December 2020 to December 2022 .

Patients were randomly assigned into one of two groups according to anesthetic drugs used (18 patients in each group) using a computerized software program (Excel Random Sample Software version 7.0). Group (T) in which patients received TIVA only and group (M)) in which patients received TIVA plus partial muscle blockade.

Inclusion Criteria:

Patients with AIS with age between (10-18) years of both sex, American Society of Anesthesiologists **(**ASA) physical status class (I, II), BMI < 30 kg/m² who were scheduled to undergo elective adolescent idiopathic scoliosis corrective surgery with cobb's angle more than 45 degree.

Exclusion Criteria:

Patients were excluded from this study if one or more of the following criteria were present: those who could not undergo MEP monitoring due to central or peripheral neuromuscular diseases such as (cerebral palsy, myasthenia gravis, acute spinal injury or neurologic shock) , patients with congenital scoliosis , patients with severe cardiac problems , implaced pacemaker , epilepsy , increased intracranial pressure or difficult airway .

Preoparative preparation:

Medical history was taken from the patients in the day before surgery. Complete clinical examinations were done to all subjects. Laboratory testing included: Complete blood count (CBC), coagulation profile (PT, PTT, and INR), Liver function tests and Kidney function tests.

All patients were investigated by Chest X ray, Cobb's angle measuring, Pulmonary function tests and Echocardiography.

All patients were kept fasting according to ASA guidelines (8 h for fatty meal , 6 h for light meal and 2 h for clear fluids). Before entering the patient to operating room , rapid history was taken and clinical examination was done .Intravenous cannula was inserted and midazolam 0.03 mg/ kg IV was given with oxygen mask to all patients .

Induction and Maintenance of anesthesia :

Routine ASA monitors were placed including (pulse oximetry, blood pressure monitoring , ECG, and temperature probe) . Another wide bore cannula (18 gauge) was inserted in additional to central venous line inserted before, then patients were randomly allocated into 2 equal groups:

Group T (TIVA only group): Patients received TIVA including propofol , dexmedetomidine and fentanyl . Induction was done by propofol (2–3 mg /kg) , dexmedetomidine (1 µg / kg) over 20 minutes fentanyl (2–3 µg / kg) and xylocaine puff spray 10% just before endotracheal intubation . Then patients were maintained by : propofol infusion at 12 mg /kg/h for 10 min, then 10 mg / kg / h for next 10 min and continued at 8 mg/kg /h , dexemedetomidine (0.2-0.7 µg / kg / h) and fentanyl (1-2 mcg/kg/hr).

Group M (TIVA with partial muscle blockade group): Patients received TIVA including propofol , dexmedetomidine ,fentanyl plus small dose of rocuronium . Induction was done by: propofol (2–3 mg/kg) , dexmedetomidine (1 µg / kg) over 20 minutes ,fentanyl (2–3 µ g/ kg) , xylocaine puff spray 10% then endotracheal intubation was done with the aid of rocuronium (0.6 mg /kg). Then patients were maintained by : propofol infusion at 12 mg /kg/h for 10 min, then 10 mg / kg / h for next

10 min and continued at 8 mg/kg/h , dexemedetomidine (0.2-0.7 µg / kg / h) , fentanyl (1-2 mcg/kg/hr) and rocuronium (0.6 mg /kg /h) .
After ensuring adequate ventilation, endotracheal tube was inserted ,secured and connected to capnography, then the patient was connected to mechanical ventilation (TV 5 ml/kg , RR 16 breath/min , I:E ratio 1:2.5) ,ventilator parameters were adjusted to keep EtCO2 35-40 mmHg and vital parameters were recorded (HR, mean arterial blood pressure , SpO2 and EtCO2). An arterial cannula was inserted after local infiltration of 1% lidocaine over the insertion site (the radial artery of the nondependent hand) . Urinary catheter was inserted the patient turned to the prone position with it's precautions regarding rechecking of endotracheal tube, hemodynamics changes and pressure points . Adjustment of the infusion rate of the anesthetic drugs to achieve the desired clinical effect.
Our target in both group was to achieve MAP of 60-65 mmHg. I.V fluids (Ringer lactate) was given (deficit , maintenance and third space loss were calculated and given). If mean arterial blood pressure become less than 50 mmHg , titration of propofol or dexmedetomidine was done , ephedrine was used if needed. If bradycardia developed (HR less than 20 % of basal HR), titrate dexmedetomidine, atropine was used if needed . Blood transfusion was ready if needed.

Intraoperative Monitoring:
All vital signs were observed before induction of anesthesia (baseline readings) , post induction of anesthesia , post positioning of the patient and then every 10 minutes but recorded every one hour for the research purposes till the end of surgery . Electrodes inserted usually after patient was anesthetized and mechanically ventilated. SSEPs and MEPs was assessed using (Medtronic NIM Eclipse system E4 made in USA manufactured in 2019) before skin incision (baseline) , after 30 minutes , post anchor insertion , post rod insetion and 30 minutes after last instrumentation completed .
A reference waveform was obtained before commencement of any spinal surgery or instrumentation usually from the upper limb to distinguish the cause of any change in the waves' amplitude and latency intraoperatively either from anesthetic cause or technical cause . During surgery the evoked potential waveforms was identified, their repeatability was assessed and the responses were monitored against a reference waveform throughout the surgical procedure . Waveforms were identified regarding upper limb (RT side) and lower limb (both Rt and Lt side) .
Motor Evoked Potentials (MEPs) :
Corkscrew stimulating electrodes were placed on the skull according to the international 10-20 EEG system .For the upper extremeties , the electrodes were placed at C3-C4 locations and at C1-C2 for the lower extremities then responses were picked up from the muscles of upper limb (commonly abductor pollicis brevis) and lower extremities (typically the tibialis anterior and gastrocnemius).The time it takes for the electrical impulse to travel from the stimulation site to the recording site is called the latency (measured in milliseconds (ms) while the size of the response called the amplitude and measured by millivolts (mv). Amplitude of the waveforms were labeled and compared to the reference waveform of the upper limb. Whenever possible the corticospinal pathways of the spinal cord were monitored using Motor Evoked Potentials across the site of surgery. Stimulation via electrodes placed on the scalp over the motor cortex area. Optimizing the MEP stimulus parameters were recommended. Bilateral recording from one or more muscles on each leg was indicated. Common sites include: Tibialis anterior and Abductor hallucis but other muscles recording sites may be required depending upon the type and level of surgery.
The recording of control upper limb MEPs was recorded above the site of the surgery , Common sites for muscles above the site of surgery include small hand muscles, Forearm flexors, forearm extensors, deltoids etc. depending upon the type and level of surgery to help better distinguish technical and systemic changes from significant changes in spinal cord function related to the surgery. A predetermined MEP warning criterion was established that includes a repeatable significant change of the waveform that cannot be explained by reversible technical or systemic causes. For spinal cord monitoring disappearance of the MEP is a major alert criterion . Other criteria may be appropriate depending upon the variability of the waveforms preceding the change. These moderate criteria may include abrupt amplitude reduction by 80% . Abrupt threshold elevation (>100V) may be a valid criterion.

Fig (1): Motor evoked potentials of both right and left lower limbs.

Somatosensory Evoked Potentials (SSEPs) :
Both latency and amplitude of the waveforms were labeled and also compared to the reference waveform of the upper limb. SSEPs stimulating electrodes were placed over bilateral posterior tibial nerves behind the medial malleolus and over median nerve at the wrist . Stimulating intensity was 50 to 60 mA at duration of 200 to 400 ms . Recording electrodes were placed over the scalp and high cervical location .

A predetermined SSEP warning criterion was established that defines a significant repeatable change in amplitude and/or latency of the waveform that cannot be explained by reversible technical or anesthetic changes. Common SSEP alert criteria include: Disappearance of waveform , Amplitude reduction (50% or more) , Latency increase (10% or more) or any changes that cannot be explained technically or anesthetically.

Depth of anesthesia by SEF which detect the cortex activity by oscillations on the spectrogram .This spectrogram uses four frequency bands : 8-12 Hz ,12-30 Hz, 0.5-4 Hz and 4-8 Hz. Adequate anesthesia was suggested when the frequency band used was from 8-12 Hz, which is the alpha activity .A risk of beta activity more than 12 Hz in addition to the alpha activity which is equivalent to lighter sedation. Less than 8 Hz slowing of the waves gradually till burst suppression and isoelectricity occurred .

Surgeon satisfaction was recorded regarding the quality of the surgical field according to a 5-point Likert scale (5: excellent, 4: Good, 3: Satisfactory, 2: Poor, 1: Very poor) **(6).**

Recovery:
After completion of surgery, stop of drug infusion was done then the patient was repositioned in the supine position , muscle relaxant was reversed in group (M) with sugamadex 2mg /kg then the patient was extubated after fulfilling extubation criteria (adequate spontaneous respiration ,adequate oxygen saturation) ,patients fully awake (eye opening ,facial grimace and purposeful movement) then patients were transferred to Intensive Care Unit (ICU).

From each patient the following data were collected :
Patient characteristics (Age , Gender, Physical state ASA ,Weight, BMI).Hemodynamics (Heart rate ,MAP).Respiratory profile (SpO2 % , EtCO2).SSEPs , MEPs (amplitude and latency) and TOF count .Depth of anesthesia by SEF. Surgeon satisfaction according to a 5-point Likert scale **(6)** .Need for blood transfusion. Recovery characteristics upon completion of the procedure (Time to eye opening, Time to follow commands ,Time to tracheal extubation).

Statistical analysis
Data were collected , tabulated , fed to the computer and analyzed using IBM SPSS software package version 20.0**.** (Armonk, NY: IBM Corp). Qualitative data were described using number and percent. The Shapiro-Wilk test was used to verify the normality of distribution. Quantitative data were described using range (minimum and maximum), mean, standard deviation, median and interquartile range

(IQR). Significance of the obtained results was judged at the 5% level. Chi-square test, Fisher's Exact or Monte Carlo correction, Mann Whitney test, Student t-test, ANOVA with repeated measures, Friedman's test (Fr test) were used.

Results:

This prospective randomized comparative study was conducted on 36 patients with scoliosis at zagazig university hospitals. The studied patients were divided into two groups.

Group T (TIVA only group) (n=18): Patients received TIVA including propofol , dexmedetomidine and fentanyl.

Group M (TIVA with partial muscle blockade group) (n= 18): Patients received TIVA plus small dose of rocuronium..

The study flow chart is shown in (Fig. 5), 36 consecutive patients with scoliosis seen during the study period, 16 (44.4%) males and 20 (55.6%) females were eligible and included in the study. The mean age was 14.5 ± 2.32 years.

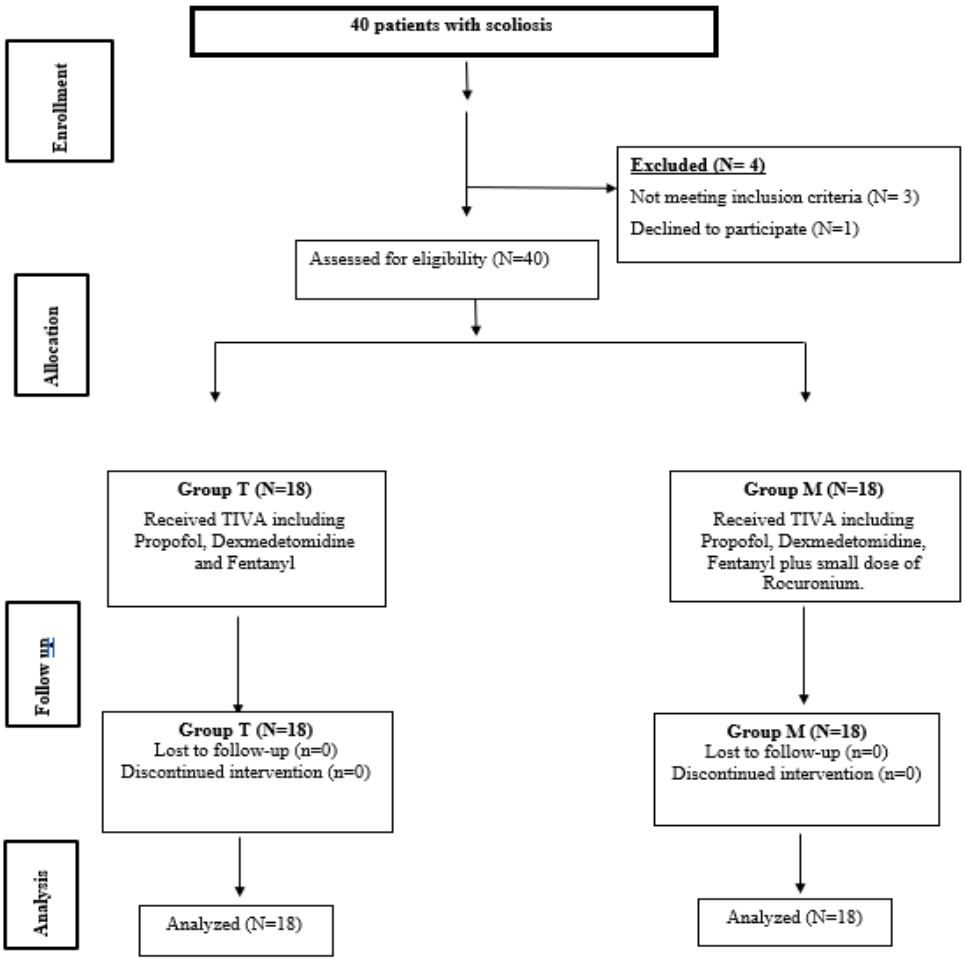

Fig (2): study flowchart

Table (1): Socio-demographic characteristic between the studied groups.

Demographic Data		Group T (n = 18)		Group M (n = 18)		Test value	P-value
		N	%	N	%		
Gender	Male	9	50.0%	7	38.9%	X^2= 0.067	0.795
	Female	9	50.0%	11	61.1%		
Age (years)	Mean± SD	14.44± 2.55		14.56± 2.15		^{Z}MWU= 0.255	0.799
BMI (Kg/m^2)	Mean± SD	26.07± 3.05		25.80± 2.63		T= 0.282	0.780
ASA	I	11	61.1%	11	61.1%	X^2= 0.00	1.00
	II	7	38.9%	7	38.9%		
Duration of surgery (hrs.)	Mean± SD	5.35± 0.35		5.26± 0.04		T= 1.08	0.286

P value< 0.05 is significant, P value< 0.01 is highly significant, SD: Standard deviation, T: Student T test

There was no statistically significant difference between the two groups regarding gender, age, BMI, ASA and duration of surgery (p>0.05) as shown in Table (1).

Table (2): Motor Evoked Potentials (MEPs's) amplitude (microvolt (µV)) at different sites and different follow-up periods

	Group T (n = 18)		Group M (n = 18)		Mann-Whitney U Test	
	Mean	± SD	Mean	± SD	Test value	P-value
MEPs (µV) (UL Amplitude)						
Baseline	1787.44	369.41	1004.33	209.79	4.905	**<0.001***
At 30 min.	1668.56	356.35	1002.78	209.59	4.778	**<0.001***
Post Anchor	1830.89	472.17	1000.94	209.63	4.873	**<0.001***
Post Rod	1793.61	261.65	1001.78	204.25	5.031	**<0.001***
After last instrumentation	1692.56	552.07	1001.64	214.04	3.924	**<0.001***
P-value	0.199		0.239			
MEPs (µV) (Right LL Amplitude)						
	Mean	± SD	Mean	± SD	Mann-Whitney U Test	
					Test value	P-value
Baseline	542.83	116.42	431.00	128.81	-2.548	**0.011***
At 30 min.	521.11	106.17	431.39	124.50	-2.310	**0.021***
Post Anchor	522.89	104.80	405.39	89.39	-2.943	**0.003***
Post Rod	532.11	109.43	402.67	105.41	-3.102	**0.002***
After last instrumentation	532.17	121.53	427.17	65.41	-2.627	**0.009***
P-value	0.068		0.064			
MEPs (µV) (Left LL Amplitude)						
	Mean	± SD	Mean	± SD	Mann-Whitney U test	
					Test value	P-value
Baseline	530.06	85.22	418.72	136.81	-2.931	**0.006***
At 30 min	498.11	94.37	417.78	132.85	-2.091	**0.044***
Post Anchor	498.11	94.37	417.78	132.85	-2.893	**0.007***
Post Rod	518.22	81.23	414.78	128.11	-3.673	**0.001***
After last instrumentation	524.11	84.61	404.50	109.21	-2.859	**0.007***
P-value	0.071		0.486			

p≤0.05 is considered statistically significant, p≤0.01 is considered highly statistically significant, SD: standard deviation, Comparison between group done by Mann-Whitney U Test & Student T test.

MEPs's amplitude (microvolt) of UL , Right LL and Left LL was significantly higher in group T compared to group M at baseline, at 30 minutes, post Anchor, Post Rod and after last instrumentation

(p<0.001). In group T and group (M) no statistically significant difference through different follow up times (p>0.05) as shown in Table (2).

Table (3): Somatosensory evoked potentials (SSEPs) latency (millisecond (ms)) at different sites and different follow-up periods

	Group T (n = 18)		**Group M (n = 18)**		**Mann-Whitney U Test**	
	Mean	**± SD**	**Mean**	**± SD**	**Test value**	**P-value**
SSEPs (ms) (UL Latency)						
Baseline	34.72	5.18	35.85	5.59	0.936	0.349
At 30 min.	35.28	5.11	38.51	5.96	1.906	0.057
Post Anchor	34.75	4.93	37.16	5.15	1.585	0.113
Post Rod	34.81	4.78	37.31	6.00	1.521	0.128
After last instrumentation	34.28	5.49	36.49	3.85	1.077	0.282
P-value	0.633		0.523			
SSEPs (ms) (Right LL Latency)						
	Mean	**± SD**	**Mean**	**± SD**	**Test value**	**P-value**
Baseline	37.22	3.84	38.50	3.02	1.110	0.267
At 30 min.	37.11	4.17	36.94	2.73	0.524	0.600
Post Anchor	36.86	3.93	38.22	3.63	0.445	0.657
Post Rod	36.92	4.26	38.36	3.71	0.872	0.383
After last instrumentation	36.89	4.15	38.62	3.05	1.224	0.221
P-value	0.769		0.068			
SSEPs (ms) (Left LL Latency)						
	Mean	**± SD**	**Mean**	**± SD**	**Test value**	**P-value**
Baseline	40.78	3.21	40.79	1.54	0.048	0.962
At 30 min.	40.89	2.69	40.41	5.07	0.127	0.899
Post Anchor	40.28	2.75	41.48	2.42	1.161	0.246
Post Rod	40.11	2.81	40.57	4.81	0.984	0.325
After last instrumentation	40.00	3.06	42.17	3.39	1.894	0.058
P-value	0.232		0.119			

p≤0.05 is considered statistically significant, p≤0.01 is considered highly statistically significant, SD: standard deviation, Comparison between group done by Mann-Whitney U Test & Student T test.

SSEPs's latency (millisecond) of UL ,**Right LL and Left LL** was higher in group M compared to group T but there was no statistically significant difference between them at baseline, at 30 minutes, post Anchor post Rod and after last instrumentation . In group T and group M, no statistically significant difference through different follow up times (p>0.05) as shown in Table (3).

Table (4): Spectral Edge frequency (SEF) (Hz) in both groups at different follow-up periods

SEF (Hz)	Group T		Group M (n = 18)		Mann-Whitney U Test	
	Mean	± SD	Mean	± SD	Test value	P-value
At baseline	11.50	1.86	7.81	1.14	4.670	**<0.001***
At 1 h	11.50	1.01	8.17	.86	5.073	**<0.001***
At 2 h	10.86	.92	8.03	.63	4.921	**<0.001***
At 3 h	11.03	1.05	8.31	.55	4.849	**<0.001***
At 4 h	10.86	.95	8.25	.71	4.823	**<0.001***
At 5 h	10.78	1.06	8.35	.62	4.723	**<0.001***
At 6 h	11.08	1.03	8.42	.60	4.813	**<0.001***
P-value	**0.014**		**0.030**			

p≤0.05 is considered statistically significant, p≤0.01 is considered highly statistically significant, Comparison between group done by Mann-Whitney U Test & Student T test.

SEF was significantly lower in group M compared to group T at baseline, at 1 h , 2 h , 3 h , 4 h , 5 h and 6 hrs. In group T, a statistically significant difference in **SEF** through different follow up times (p=0.014). In group M, a statistically significant difference in **SEF** through different follow up times (p=0.030) as shown in Table (4).

Table (5): Train Of Four (TOF) counts at different follow-up periods

TOF counts	Group T (n = 18)		Group M (n = 18)		Mann-Whitney U Test	
	Mean	± SD	Mean	± SD	Test value	P-value
At baseline	4.0	0.0	2.2	0.4	5.721	**<0.001***
At 1 h	4.0	0.0	2.0	0.0	5.916	**<0.001***
At 2 h	4.0	0.0	2.0	0.0	5.916	**<0.001***
At 3 h	4.0	0.0	2.0	0.0	5.916	**<0.001***
At 4 h	4.0	0.0	2.0	0.0	5.916	**<0.001***
At 5 h	4.0	0.0	2.0	0.0	5.916	**<0.001***
At 6 h	4.0	0.0	2.0	0.0	5.916	**<0.001***
P-value	0.858		0.238			

p≤0.05 is considered statistically significant, p≤0.01 is considered highly statistically significant, Comparison between group done by Mann-Whitney U Test & Student T test.

TOF counts was significantly lower in group M compared to group T at baseline, at 1 h , 2 h , 3 h , 4 h , 5 h and 6 h (p<0.001). In group T, no statistically significant difference in **TOF** through different follow up times (p>0.05). In group M, a statistically significant difference in **TOF** through different follow up times (p>0.05) as shown in Table (5).

Table (6): Recovery characteristics in both groups :

Time (min)	Group T (n = 18)		Group M (n = 18)		Mann-Whitney U Test	
	Mean	± SD	Mean	± SD	Test value	P-value
Time to Eye Opening	12.44	2.12	6.00	1.46	5.154	**<0.001***
Time to follow commands	15.44	2.09	9.50	1.62	5.062	**<0.001***
Time of tracheal extubation	19.22	3.75	12.94	2.01	4.760	**<0.001***

p≤0.05 is considered statistically significant, p≤0.01 is considered highly statistically significant, Comparison between group done by Mann-Whitney U Test & Student T test.

Time to eye opening (min) ,Time to follow commands and Time of tracheal extubation was significantly lower in group M compared to group T (p<0.001) as shown in Table (6).

Table (7): Hemodynamics (HR&MAP) at different follow-up periods

HR(B/m)	Group T (n = 18)		Group M (n = 18)		**Student T Test**	
	Mean	± SD	Mean	± SD	Test value	P-value
At baseline	70.17	10.53	76.61	7.41	1.462	**0.041***
Post Induction	64.78	7.66	70.11	6.29	2.019	**0.029***
Post Positioning	61.44	8.37	67.06	4.22	1.286	**0.018***
At 1 h	62.17	4.15	66.11	3.46	0.829	**0.004***
At 2 h	61.44	3.97	66.50	2.85	0.048	**0.001***
At 3 h	61.22	3.49	67.56	2.89	1.248	**0.001***
At 4 h	61.72	3.58	67.28	3.01	0.504	**0.001***
At 5 h	62.06	3.62	67.06	4.04	0.00	**0.001***
At 6 h	62.17	4.26	66.56	3.54	0.468	**0.002***
P-value	0.073		0.125			
MAP(mmHg)	Mean	± SD	Mean	± SD	Mann-Whitney U Test	
					Test value	P-value
At baseline	71.44	7.35	76.39	5.90	1.699	**0.029***
Post Induction	67.39	7.48	72.28	6.40	1.334	**0.017***
Post Positioning	61.67	7.90	69.67	7.43	1.454	**0.002***
At 1 h	63.39	3.58	69.00	4.34	0.864	**0.001***
At 2 h	61.33	6.60	67.72	4.71	0.981	**0.013***
At 3 h	62.56	1.72	68.11	3.45	1.394	**0.001***
At 4 h	60.39	3.05	67.56	3.40	1.467	**0.001***
At 5 h	60.72	3.10	67.89	2.61	1.565	**0.001***
At 6 h	61.11	2.68	67.06	2.46	0.958	**0.001***
P-value	0.481		0.205			

p≤0.05 is considered statistically significant, p≤0.01 is considered highly statistically significant,

Heart rate (Bpm) and MAP (mmHg) showed significant decrease in group T compared to group M at baseline, post induction, post positioning , 1 h , 2 h , 3 h , 4 h , 5 h and 6 h (p>0.05). In group T and group (M) no statistically significant difference in **heart rate or MAP** through different follow up times (p>0.05) as shown in Table (7).

Table (8): SpO2 (%) at different follow-up periods

SpO2 (%)	**Group T (n = 18)**		**Group M (n = 18)**		**Mann-Whitney U Test**	
	Mean	**± SD**	**Mean**	**± SD**	**Test value**	**P-value**
At baseline	99.61	0.50	99.83	0.38	1.468	0.142
Post Induction	99.61	0.50	99.56	0.51	0.329	0.744
Post Positoning	99.39	0.50	99.39	0.50	0.000	1.000
At 1 h	99.44	0.51	99.50	0.79	0.795	0.426
At 2 h	99.83	0.38	99.83	0.38	0.000	1.000
At 3 h	99.44	0.78	99.28	0.57	1.194	0.232
At 4 h	99.94	0.24	100.00	0.00	1.000	0.317
At 5 h	99.89	0.32	100.00	0.00	1.435	0.151
At 6 h	99.72	0.57	99.39	0.50	1.854	0.072
P-value	0.104		0.056			

p≤0.05 is considered statistically significant, p≤0.01 is considered highly statistically significant,

No significant difference between group T and group M at baseline, post induction, post, 1 h , 2 h , 3 h , 4 h , 5 h and 6 h (p>0.05).In group T and group (M) , no statistically significant difference in SPO2 through different follow up times (p>0.05) as shown in Table (8).

Table (9): Surgeon satisfaction in both groups.

Surgeon Satisfaction	Group T (n = 18)		Group M (n = 18)		Chi- Square test	
	N	%	N	%	Test value	P-value
Excellent 5	5	27.8%	13	72.2%	X^2= 7.438	**0.024***
Good 4	12	66.7%	5	27.8%		
Satisfactory 3	1	5.6%	0	0.0%		

P value< 0.05 is significant, P value< 0.01 is highly significant, SD: Standard deviation,

Regarding surgeon satisfaction, 27.8% had excellent , 66.7% had good results and 5.6% scored satisfactory in group T. While in group M, 72.2% had excellent results and 27.8% had good results. There was statistically significant difference between the two groups regarding surgeon satisfaction (p=0.024) as group M showed better satisfaction as shown in Table (9).

Table (10): Operative data regarding blood transfusion and blood loss (ml) .

Operative Data		Group T (n = 18)		Group M (n = 18)		Test value	P-value
		N	%	N	%		
Blood Transfusion	**No**	1	5.6%	5	27.8%	X^2= 3.20	0.177^{FET}
	Yes	17	94.4%	13	72.2%		
Blood loss (ml)	**Mean± SD**	627.78± 170.83		397.22± 111.77		^{Z}MWU= 3.785	**0.001***

P value< 0.05 is significant, P value< 0.01 is highly significant, SD: Standard deviation, ^{Z}MWU = Mann- Whitney U test, X^2= Chi- Square test, FET: Fischer exact test

No significant difference between group T and group M regarding **blood transfusion** (p>0.05) but regarding **Blood loss (ml)** there was statistically significantly lower in group M compared to group T (p<0.001) as shown in Table (10).

Discussion

Deformity corrective surgery is effective for spinal scoliosis disorders as (idiopathic, congenital, neuromuscular, and syndrome related), but iatrogenic spinal cord complication is still a potential risk. According to the Scoliosis Research Society, such surgery has an estimated 1% incidence of neurological complications, which rises to 1.87% when a combination surgical technique is used. Postoperative neurological complications in scoliosis can be classified as direct or indirect complications. Direct complications, which are usually iatrogenic, include laceration, avulsion, and compression injuries. Indirect complications include ischemia related to compression, excessive retraction, or postoperative hematoma, so neuromonitoring intraoperatively became focused to avoid those complications **(7)**.

Quick identification of impending spinal cord injury opens the window of opportunity to the surgeon and anesthesiologist to act before the injury becomes irreversible.

In the present study patients suffering from AIS undergoing scoliotic corrective surgery categorized into two groups : group receiving only TIVA ,other one receiving TIVA with partial muscle relaxant . Our study was done to detect the possibility of usage of muscle relaxant during neurophysiological monitoring without interruption of MEPs and SSEPs waves. We used rocuronium with dose of 0.6 mg/kg/h in addition to propofol , dexemedetomidine and fentanyl . Also, we detect it's effect on TOF ,SEF , hemodynamics (HR and MAP) , recovery characteristics including (time to eye opening ,time to follow commands and time of tracheal extubation).

In order to identify impending damage to the nervous system before it is irreversible, a set of so-called 'warning criteria' were proposed. These warning criteria can be rightfully triggered by surgical manipulation. However, anesthesia can also significantly impact the efficacy of the neurophysiologic measurements, potentially triggering warning criteria. Ideal muscle relaxation should meet the operational requirements, avoid interference with surgical operations and allow MEP monitoring. Some studies have shown that partial neuromuscular blockade can provide the right monitoring conditions for neurophysiological monitoring an d improve the safety of anesthesia and surgery **(8)**

Regarding MEPs amplitude in the current study at different follow- up periods, it was revealed that MEPs' amplitude of upper limb and both lower limbs was significantly higher in group T compared to group M at baseline, at 30 minutes, post Anchor, Post Rod and when instrumentation was completed (p<0.001). In both groups there was no statistically

significant change in MEPs's amplitude of UL through different follow up times (p>0.05).
In agreement with the current study , **Ko et al., 2018 (9)** in which 80 patients who underwent neurointervention with MEP monitoring were randomaly assigned into 2 groups (group with intermittent bolus of rocuronium and group with continuous infusion of rocuronium) revealed that MEP amplitude was also lower while using continuous dose of rocuronium . That study concluded that continuous infusion of rocuronium effectively inhibited MEP amplitude and decreased TOF counts with enabling MEP monitoring .
Also, in concordance with the current study **Kim et al., 2013 (10)** compared the effects of different levels of neuromuscular block (NMB) including no and partial neuromuscular block (NMB) on MEP parameters among 120 patients undergoing neurosurgeries.the patients were randomly allocated to four groups :Group A was to maintain two TOF counts ,Group B was to maintain a T1/Tc of 0.5 ,Group C T2/Tc of 0.5 (T1,2 means first or second twitch height of TOF ;Tc,control twitch height),Group D didn't maintain NMB. The study revealed that the mean MEP amplitude values were largest under no NMB compared to any level of neuromuscular block but still can be assessed and therefore it doesn't alter MEP amplitude monitoring
In agreement with this study , **Zhang et al., 2021 (11)** who concluded 120 patients undergoing spinal surgery were allocated into three groups with different doses of rocuronium (0.6-0.9-1.2 mg /kg/h) and revealed that no significant difference regarding MEP amplitude except in single time(before spinal canal decompression) with dose of 1.2 mg/kg/h but the dose of 0.6 and 0.9 mg/kg/h doesn't alter MEP amplitude.
In disagreement with our study , **Liu et al., 2019 (12)** who aimed to examine the effects of NMB on motor evoked potentials and to determine an appropriate level of partial neuromuscular blockade (pNMB) for MEPs during surgical correction of idiopathic scoliosis under total intravenous anesthesia (TIVA) revealed that the reductions in amplitude probably represent reductions in number and timing of excited motor units responding to transcranial electric stimulation and the appropriate regimen for MEPs monitoring was when train of four ratio (TOF ratio) at 26-50%.This difference in results between that study and our study may be due to the incongruent sensitivities of the involved muscle groups to NMB agents ,also in that study Cis-atracurium was used not rocuronium .

Regarding somatosensory evoked potentials (SSEPs) amplitude of UL , Right and left LL at different follow-up periods (at baseline, at 30 minutes, post Anchor, Post Rod. And after last instrumentation) , the current study showed that there was no statistically significant difference between group T and group M (p >0.05). In both groups there was no statistically significant change in SSEPs amplitude of UL, Right and left LL through different follow up times (p>0.05). In **Zhang et., al 2021(11),** there was no significant difference in the three groups with different doses of Rocuronium as in our study .

Regarding SSEPs latencies at different follow-up periods the current study showed that there was higher latencies in group (M) but there is no statistically significant difference between group T and group M in UL, Right and left LL at baseline, at 30 minutes, post Anchor, Post Rod. and after last instrumentation (p>0.05). In agreement with the current study **Sloan, 1994 (13)** showed that there were no statistically significant changes for SSEPs latency measured at any degree of neuromuscular blockade when compared with values obtained in the unblocked control state. Also, in agreement with **Liu et.,al 2019 (12)** the study revealed that the use of pNMB resulted in increased latencies while using partial dose of NMB specially with TOF1(one or two of TOF counts) compared with nNMB while no dramatic changes were observed at TOF 2-5 (TOF2 :one or two TOF counts ; TOF3 :TOFR 10-25% ; TOF4 :TOFR 26-50% ;TOF5: TOFR 51-75%).
Regarding SEF in this study , it was significantly lower in group M compared to group T and there was significant difference through different follow up periods in both groups . A narrative review by **Jildenstål et al., 2022 (14)** was undertaken to examine the available research evidence on the effect and reliability of spectral edge frequency (SEF) for assessing the depth of anaesthesia in adult patients under general anesthesia, and revealed that suggest that SEF varies according to the anesthetic drugs used.
Regarding TOF response in our study after use of rocuronium (0.6 mg/kg/h) was maintaing TOF count two to three and so there was significant difference between both groups. MEP amplitude can be optimally assessed with TOF count 2-3 . **Ko et., 2018 (9)** in agreement with our study revealed that maintainance of the TOF count between 2 to 3 with the rocuronium infusion rate of 5mcg/ kg/min was sufficient and also monitoring of the MEPs were successful . Additionally, it was noted that the MEP variability was more favorable when rocuronium was continuously infused. **Zhang et., al 2021 (11)** , TOF counts between (2-3) with the dose of 0.6 mg /kg/h allow good monitoring of MEPs amplitude as in our study but that study concluded that 0.9 mg/kg/h is the most appropriate dose for monitoring ,this difference between both studies may be because in our study we didn't use such that dose .
Regarding recovery characteristics , it was revealed that time to eye opening, time to follow commands and time of tracheal extubation was significantly

lower in group M compared to group T ($p<0.001$) so better recovery characteristics were in group M . However, **Ko et al., 2018 (9)** stated that the continuous infusion of neuromuscular blocking drugs (NMBD) can be a cause of delayed emergence and remaining paralysis after reversal of NMBD, and these factors can threaten the patient safety.This disagreemwnt with this study may be due to the difference in number of patients as it was about 80 patients in that study. Additionally, it is evident that an incomplete reversal from NMBD can lead to severe hypoventilation and hypoxia after extubation in the patient. These could be the main reasons why anesthesiologists do not prefer the infusion of NMBD when working with patients. But, after sugammadex was introduced, the rapid and complete reversal from NMB became possible. In this study individualized dose of sugammadex as determined by the TOF count, made no difference in the measured emergence time between the studied groups.

Regarding the effect on hemodynamics in this study HR and MAP were significantly lower in group T than group M . Our study disagreed with **Ko et al., 2018 (9)** which reported that there was no significant difference between the groups of TIVA with or without partial muscle blockade as regard hemodynamics.

This conflict may be due to the difference in sample size which is 80 patients in that study ,also may be due to the difference in TIVA used as that study used propofol and remifentanyl without dexemedetomidine.

Regarding surgeon satisfaction, 5.6% scored satisfactory , 66.7% had good results and 27.8% had excellent results in group T. While in group M, 27.8% had good results and 72.2% had excellent results. There was statistically significant difference between the two groups regarding surgeon satisfaction ($p=0.024$) as group M showed better satisfaction. In agreement with the current study **Oh et al., 2019 (15)** investigate operating conditions and overall satisfaction of surgeons using deep neuromuscular blockade (NMB) vs no NMB in patients undergoing lumbar spinal surgery under general anesthesia, and revealed that, deep NMB provides better operating conditions and higher overall satisfaction compared to no NMB in lumbar spinal surgery. Surgeons and patients were more subjectively and objectively satisfied with deep NMB than with no NMB.

Regarding operative data (blood transfusion and blood loss) in this study , there was no significant difference in both groups regarding blood transfusion .However, blood loss was statistically significantly lower in group M compared to group T ($p<0.001$). In agreement with the current study **Oh et al., 2019 (15)** showed that deep NMB provides lower blood loss compared to no NMB in lumbar spinal surgery.

Limitation: The current study was limited in a single study center . Further comparative studies with larger sample size , multi-center and with different doses of rocuronium to confirm the results of the study .

Conclusion:

The current study showed that infusion of partial dose of muscle relaxant (Rocuronium) effectively inhibit the involuntary movement and facilitate tracheal intubation without disturbing the motor or sensory evoked potential variability in corrective surgery of scoliosis . Additionally, better recovery characteristics, lower blood loss , higher surgeon satisfaction and favorable depth of anesthesia was found in partial neuromuscular blockade

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