

A prospective observational study to evaluate the magnitude of temperature changes in children undergoing elective MRI under general anesthesia

ABSTRACT

Context: Induction of general anesthesia and mandatory low-ambient temperature in the magnetic resonance imaging (MRI) suite renders the pediatric patient prone to fall in core temperature. Previously done studies have shown mixed results with core temperature showing both rise and fall.

Aims: The aim of this study is to evaluate which effect, hypothermia or hyperthermia, predominates in children anesthetized for MRI. Is the change in temperature the same across age groups and for different MRI scanners?.

Settings and Design: Prospective, observational study in a tertiary care teaching hospital.

Subjects and Methods: Two hundred and fifty children of age between 1 month and 16 years scheduled for MRI under propofol-based total intravenous anesthesia (TIVA) were recruited. A baseline core temperature (pre-scan) was recorded with the pediatric nasopharyngeal temperature probe after induction of anesthesia and also after the scan in the recovery room.

Results: The study shows that there is a significant fall in temperature of 1.022°C (CI = 0.964, 1.081) following MRI ($P < 0.001$) but the difference across different age groups and type of MRI scanner used are not significant. There is a significant correlation between duration in the MRI room and a decrease in temperature (P value = 0.003). Using simple linear regression analysis, it is found that if there is a 1-min increase in the duration of MRI, there is a decrease of 0.006°C in temperature.

Conclusion: Vigilant temperature preservation strategies have to be maintained during the time the anesthetized child is present in the MRI suite. MRI compatible active warming devices are warranted especially in high turnover centers.

Key words: General anesthesia; hypothermia; magnetic resonance imaging; pediatrics; propofol TIVA

Introduction

Magnetic resonance imaging (MRI) has emerged as a preferred diagnostic tool especially in children, being a nonionizing method for accurate diagnosis of soft tissue lesions. The environment is noisy and it can be claustrophobic inside the MRI suite. In addition to this, the long exam times require children

to be immobile which mandates anesthesia/sedation. The induction of general anesthesia and mandatory low ambient temperature in the MRI suite renders the pediatric patient prone to fall in core temperature.^[1,2] Sedation/anesthesia causes impairment of thermoregulatory control which can cause 1–3°C drop in the core body temperature.^[3,4] Conversely, the

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Ruth MS, Sridharan N, Rai E, Joselyn AS. A prospective observational study to evaluate the magnitude of temperature changes in children undergoing elective MRI under general anesthesia. Saudi J Anaesth 2020;14:200-5.

Access this article online	
Website: www.saudija.org	Quick Response Code 
DOI: 10.4103/sja.SJA_791_19	

MERLIN S. RUTH, NIVETHA SRIDHARAN¹, EKTA RAI, ANITA S. JOSELYN

Departments of Anaesthesia and ¹Biostatistics, Christian Medical College and Hospital, Vellore, Tamil Nadu, India

Address for correspondence: Dr. Anita S. Joselyn, Department of Anaesthesia, Christian Medical College and Hospital, Vellore - 632 004, Tamil Nadu, India. Email: anjeyanth@gmail.com

Submitted: 19-Dec-2019, **Accepted:** 16-Jan-2020, **Published:** 05-Mar-2020

MRI scanner generates radio-frequency radiation (RFR), which is absorbed by the patient. Even if clinically relevant warming of the body caused by RFR, is unlikely during routine MRI in adults, the large surface area–bodyweight ratio of children may potentially result in an increase in body temperature which can be up to 1°C.^[5-7] Studies done previously in children have shown mixed results with core temperature showing both rise and fall^[8,9] but to the degree of less than 0.5°C only. Temperature management for children in the MRI suite is complicated because it is difficult to monitor temperature during the MRI scan and MRI compatible monitoring devices and active warming devices are expensive.

We have postulated that core temperature changes more than $\geq 0.5^\circ\text{C}$ from baseline, which can be either hypothermia or hyperthermia, warrants active intervention with a change in protocol for temperature management in MRI suite. Secondary questions are: is the change the same across age groups and across different MRI scanners (1.5T or 3T)? Estimating temperature change and the degree of change will aid better temperature management strategies, especially in developing countries where economic constraints are available in procuring MRI compatible equipment.

Subjects and Methods

This is a prospective observational study done in a tertiary care teaching institute in south India. After getting approval from the institutional review board, (IRB no. 10907) we recruited consecutive 250 children of age between 1 month and 16 years scheduled for MRI under anesthesia during the 5-month period between November 2017 to March 2018. Children having a temperature of greater than 37.2°C or lesser than 36°C , children with bleeding disorders and upper airway obstruction symptoms, and children undergoing emergency scan were excluded. Written informed consent was obtained from all parents/guardians. None of the patients had sedative premedication prior to the procedure. All eligible patients were subjected to inhalational induction in the anesthesia room of the MRI suite. Intravenous access was achieved following which anesthesia was maintained with propofol total intravenous anesthesia (TIVA). The dose of propofol used was 1 mg/kg IV after induction followed by 100–125 mcg/kg/min. A baseline core temperature (pre-scan) was recorded with the pediatric nasopharyngeal temperature probe (Philips Medical Systems, 10 Fr probe) inserted by the consultant anesthetist. The nasopharyngeal probe was inserted through the nostril, for a premeasured length (equal to the distance between the nostril and angle of the mandible). We gave a reading time of 45 s to 1 min to allow for equilibration with the body temperature as most of these patients were breathing spontaneously under

TIVA. All patients were wearing light clothing and were covered with a single blanket before, during, and after the scan. The MRI room temperature was maintained between 20 and 24°C . MRI of various regions was done either with 1.5T (Siemens, Avanto) or 3T (Philips, Achieva) scanners. After the MRI scan was over, the patient was shifted to the anesthesia room for recovery, wherein post-scan temperature was immediately measured and the duration of the scan was noted. If the child was found to be hyperthermic, additional blankets were used.

Sample size calculation

The sample size was calculated based on the previous study done by Lo *et al.*^[8] To detect a change in temperature of 0.5°C with a study power of 80% and an alpha error of 5% the sample size required was 28. As we wanted to analyze the difference across different age groups categorized into <1, 1–6, 7–12, >12 years and weight categories <10 kg, 10–20 kg, and >20 kg, we recruited 250 patients.

Statistical analysis

Categorical demographic variables such as age groups, weight group, and sex are presented in frequency tables. Age was categorized into less than 1 year, 1–6 years, 7–12 years, and greater than 12 years. Weight was categorized into less than 10 kg, 11–20 kg, and greater than 20 kg groups. The mean and standard deviation of the age of study subjects are also presented.

The difference between pre- and post-MRI temperature were calculated for all cases and presented graphically in the histogram. Significance was tested using a paired *t*-test. Descriptive statistics were used to describe the decrease in temperature. 95% confidence interval for the mean decrease in temperature is also presented.

The decrease in temperature across factors such as age group, weight categories, and MRI rooms are presented using appropriate descriptive statistics and box plots and significance levels were computed. ANOVA test was used for comparison among age and weight categories. An independent sample *t*-test was used for the comparison among MRI rooms. 95% confidence intervals were also computed among various factors.

Correlation between the duration and change in temperature was measured using the Pearson correlation coefficient and simple linear regression analysis. The graphical representation was made using a scatter plot.

All statistical analyses were performed using the R 3.3.2 software (<https://cran.r-project.org/>).

Results

The flowchart of patient participation is shown in Figure 1. The demographic characteristics of the study population are given in Table 1. The majority of the children belonged to the 1–6 year age group, male sex, and 10–20 kg weight category, and scans were mostly done in 3T MRI rooms. The mean age was 4 (± 2.6) years and weight was 14.83 (± 6.78) kg. The mean duration of the MRI scan was 52 \pm 14.6 min.

Table 1: Demographic characteristics of the study population

Parameters	Frequency (%)
Gender	
Male	161 (64.4)
Female	89 (35.6)
Age Groups	
<1 year	16 (6.4)
1-6 years	187 (74.8)
7-12 years	45 (18)
>12 years	2 (0.8)
Weight	
<10 kg	47 (18.8)
10-20 kg	158 (63.2)
>20 kg	45 (18)
MRI rooms	
3T	202 (80.8)
1.5T	48 (19.2)

MRI: Magnetic resonance imaging

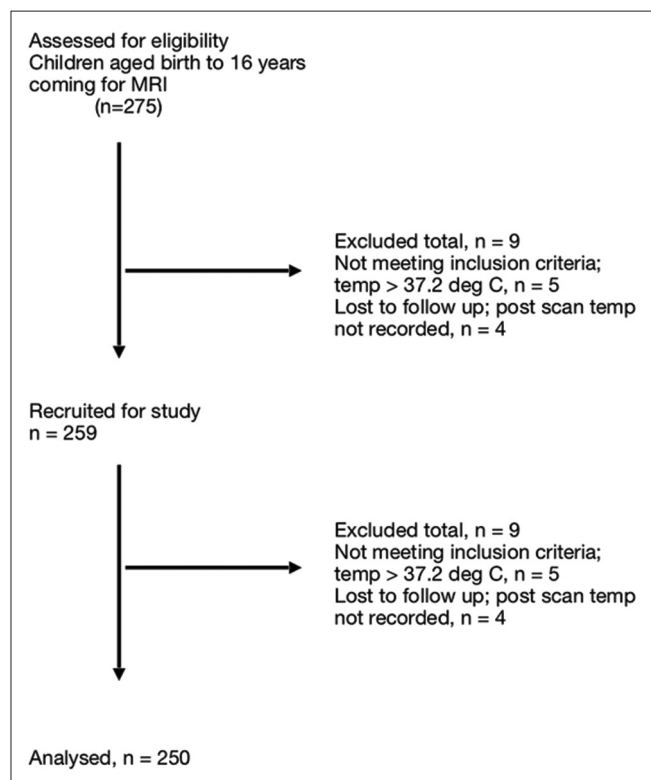


Figure 1: Flowchart depicting the flow of study participants

The study shows that there is a significant fall in temperature of 1.022°C CI (0.964, 1.081) following MRI ($P < 0.001$). Of the 250 children analyzed, three of them (1.2%) had an increase in temperature and another three (1.2%) children had no change in temperature. The rest of 244 children (97.6%) had a decrease in temperature with mean (SD) of 1.038 (0.45)°C (P -value < 0.001). The post-scan temperature chart is depicted in Figure 2. Among the children who had a post-scan decrease in temperature, 15% had a decrease of $< 0.5^\circ\text{C}$, 27% had a decrease of 0.6–1°C, and 58% had a decrease $> 1^\circ\text{C}$. The maximum decrease in the temperature observed was 2.2°C. The distribution of the decrease in temperature is given in Figure 3.

We analyzed the correlation between change in temperature and different age and weight categories. Though the overall decrease is significant, when comparing the change in temperature across different weight and age groups, the temperature change was not significant. Similarly, we also analyzed the correlation between temperature change and the type of scanner used (1.5T and 3T) for imaging. The details of the temperature change in both types of MRI scanners are given in Table 2. There was no difference in temperature change between both the types of scanners used for imaging.

The decrease in temperature has a significant positive correlation with the duration of scan ($P < 0.003$) in spite of the correlation being weak (Pearson correlation coefficient $r = 0.19$) [Figure 4]. Using simple linear regression analysis, it is found that if there is a one-minute increase in the duration of MRI, there is a decrease of 0.006°C in temperature. The predicted value can be obtained as the prediction of a decrease

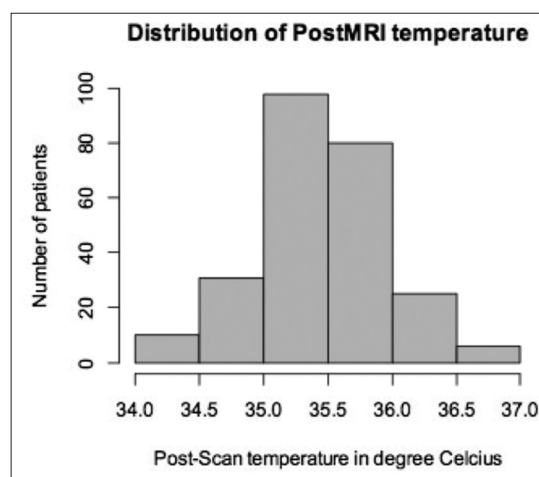


Figure 2: Distribution of post-MRI temperatures. Nasopharyngeal temperatures of 250 children who underwent magnetic resonance imaging (MRI) under general anesthesia with propofol total intravenous anesthesia (TIVA) were measured immediately before and after the scan. The post-MRI temperatures show normal distribution with mean \pm SD of 35.5 \pm 0.5°C

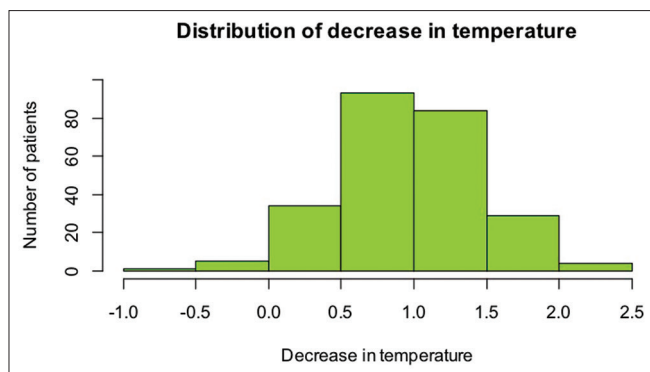


Figure 3: Distribution of decrease in temperature. Nasopharyngeal temperatures of 250 children who underwent MRI under general anesthesia with Propofol TIVA were measured immediately before and after the scan. There was a decrease in temperatures in 97.6% of children while comparing the pre and post-scan temperatures. The distribution of decrease in temperatures follows a normal distribution with a mean \pm SD of $1.04 \pm 0.45^{\circ}\text{C}$

in temperature ($y = 0.7^{\circ}\text{C} + 0.006 \times \text{duration of scan in minutes}$). ($R^2 = 0.031$). The value of 0.7°C is the portion of the decrease in temperature that occurs within the observed range of scan duration in our study. For a patient staying 1 h for MRI, the expected drop in temperature will be nearly $0.7 + 60 \times 0.006 = 1.06^{\circ}\text{C}$, for a patient staying for 2 h will be 1.42°C . Translating this into clinical practice, is this effect significant clinically and what percentage of children will have hypothermia due to increased duration of scan? The value of $R^2 = 0.031$ means that only 3.1% of the fall in temperature can be attributed to the scan duration changes. This finding of a very small (3.1%) attribution of scan duration to the decrease in temperature, adds on to the no significant correlation between age, weight groups, and types of MRI scanners to the decrease in temperature we have demonstrated earlier. These data emphasize that induction of general anesthesia *per se* is the stronger factor, overpowering the heating effect of radiofrequency radiations on temperature change resulting in a significant mean decrease in temperature of 1.04°C .

Discussion

Our study shows that there is a one-sided significant fall in temperature of 1.022°C ($\pm\text{SD } 0.472$) in children undergoing MRI under propofol TIVA anesthesia. The results concur with those by Lo *et al.* who showed a mean temperature fall of 0.3°C in anesthetized children. Whether the greater fall in mean core temperature can be attributed to the choice of anaesthetic technique (TIVA used in this study vis a vis inhalational anaesthesia with LMA in the study by Lo *et al.*) needs further research.

Our results were different from that of Bryan *et al.* and Machata *et al.* who showed a significant increase in core

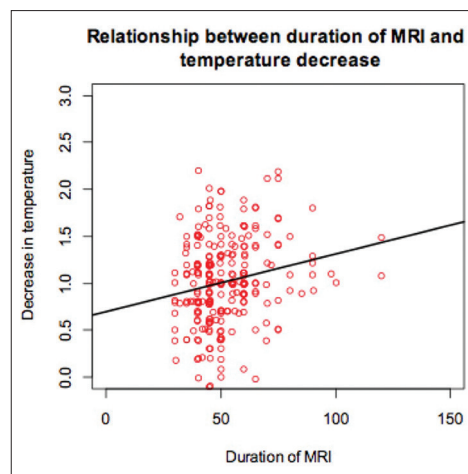


Figure 4: Relationship between temperature change and duration of MRI scan. Using simple linear regression analysis, 1-min increase in the duration of MRI is associated with a decrease of 0.006°C in temperature

Table 2: Differences in temperature changes with two types of MRI scanners

Clinical Characteristics	MRI 3T n=202	MRI 1.5T n=48	P
Pre scan temperature ($^{\circ}\text{C}$) (mean \pm SD)	36.54 \pm 0.33	36.47 \pm 0.35	0.069
Post scan temperature ($^{\circ}\text{C}$) (mean \pm SD)	35.51 \pm 0.50	35.44 \pm 0.50	0.081
Mean change in temperature ($^{\circ}\text{C}$) mean \pm SD	1.02 \pm 0.48	1.03 \pm 0.45	0.040
Direction of change in temperature	Count (%)	Count(%)	
Increase($^{\circ}\text{C}$)			
<0.5	2 (1.0)	0 (0)	
>0.5	1 (0.5)	0 (0)	
Decrease ($^{\circ}\text{C}$)			
<0.5	26 (10.4)(12.87)	8 (3.2) (16.6)	
0.6-1	55 (22) (27.2)	12 (4.8) (25)	
>1	115 (46) (56.9)	28 (11.2) (58.3)	
No change ($^{\circ}\text{C}$)	3 (1.2) (1.5)	0 (0)	
	202 (80.8)	48 (19.2)	

temperature (tympanic membrane temperature) by 0.5°C and 0.2°C , vis-a-vis 1.5T and 3T MRI machines, respectively.^[9,10] This noticed increment could be because the patients were only sedated compared to general anesthesia in our study. This is probably due to the effect of general anesthesia on the child's core temperature which is more significant than the effect of RFR.

Isaacson *et al.* and Acar *et al.* showed mixed results with the majority showing an increase in temperature in the former (under propofol sedation dose/non-sedation) and a decrease in temperature in the latter (under inhalational anaesthesia).^[11,12] But none of the studies showed as large an effect as our study.

There was no significant correlation between temperature change and different age groups, as well as weight categories. This was in contrast to the findings demonstrated by Dalal *et al.* in neonates and infants undergoing MRI under anesthesia/sedation. They have demonstrated the incidence of hypothermia had a strong correlation with low weight and younger age group categories.^[13] Similarly, we also could not demonstrate any statistical difference between the two types of MRI scanners 1.5T and 3T in relationship to the occurrence of hypothermia.

The correlation between the duration of scan and decrease in core temperature looks statistically significant but clinically only 3.1% of patients will have the probability of having a decrease in body temperature due to scan duration. This data emphasizes that the induction of general anesthesia in children *per se* is a stronger factor overpowering the heating effect of radiofrequency radiations on temperature change resulting in a significant mean decrease in temperature of 1.04°C.

Whereas the previous studies had used tympanic temperature monitoring, our study preferred to use nasopharyngeal temperature which is comparable to the esophageal temperature.^[14,15] We have used nasopharyngeal temperature measurements as it closely reflects core body temperature. Tympanic membrane temperatures, though noninvasive, quick, and easy to use, have shown to have less sensitivity in children less than 3 years due to probes being larger than their ear canals.^[16] Also, tympanic membrane temperatures are more affected by ambient temperatures of the MRI suite than esophageal temperatures.^[17] Nasopharyngeal temperature accurately reflects esophageal temperature even in the presence of leak^[18] and as it is the standard of care in patient care during surgeries, it was adopted as the method for measuring core temperature.

Limitations of this study are we did not compare the effects of TIVA vs inhalational anesthesia on core temperature. This requires further studies and meta-analysis. Also, we did not compare skin temperature with axillary temperature changes and nasopharyngeal temperatures which could have further validated our results.

Conclusion

Our study shows that a vigilant temperature preservation chain has to be maintained from the time in the MRI suite until the time the patients are with parents. MRI compatible temperature probes and active warming devices which are very expensive are warranted especially in high-turnover

centers which cater to various age and weight categories of the pediatric population.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

- Matsukawa T, Sessler DI, Sessler AM, Schroeder M, Ozaki M, Kurz A, *et al.* Heat flow and distribution during induction of general anesthesia. *Anesthesiology* 1995;82:662-73.
- Buggy DJ, Crossley AW. Thermoregulation, mild perioperative hypothermia and postanaesthetic shivering. *Br J Anaesth* 2000;84:615-28.
- Sessler DI. Perioperative heat balance. *Anesthesiology* 2000;92:578-96.
- Bissonnette B, Sessler DI. Thermoregulatory thresholds for vasoconstriction in pediatric patients anesthetized with halothane or halothane and caudal bupivacaine. *Anesthesiology* 1992;76:387-92.
- Formica D, Silvestri S. Biological effects of exposure to magnetic resonance imaging: An overview. *Biomed Eng Online* 2004 22;3:11.
- Boss A, Graf H, Berger A, Lauer UA, Wojtczyk H, Claussen CD, *et al.* Tissue warming and regulatory responses induced by radio frequency energy deposition on a whole-body 3-Tesla magnetic resonance imager. *J Magn Reson Imaging JMRI* 2007;26:1334-9.
- Allison J, Yanasak N. What MRI Sequences produce the highest specific absorption rate (SAR), and is there something we should be doing to reduce the SAR during standard examinations? *Am J Roentgenol* 2015;205:W140-W140.
- Lo C, Ormond G, McDougall R, Sheppard SJ, Davidson AJ. Effect of magnetic resonance imaging on core body temperature in anaesthetised children. *Anaesth Intensive Care* 2014;42:333-9.
- Bryan YF, Templeton TW, Nick TG, Szafran M, Tung A. Brain magnetic resonance imaging increases core body temperature in sedated children. *Anesth Analg* 2006;102:1674-9.
- Machata AM, Willschke H, Kabon B, Prayer D, Marhofer P. Effect of brain magnetic resonance imaging on body core temperature in sedated infants and children. *Br J Anaesth* 2009;102:385-9.
- Isaacson DL, Yanosky DJ, Jones RA, Dennehy N, Spandorfer P, Baxter AL. Effect of MRI strength and propofol sedation on pediatric core temperature change. *J Magn Reson Imaging* 2011;33:950-6.
- Acar HV, Yarkan Uysal H, Gunal Eruyar S, Dikmen B. Body temperature decreases in pediatric patients undergoing magnetic resonance imaging under general anaesthesia: 10AP3-4. *Eur J Anaesthesiol* 2012;29:160.
- Dalal PG, Porath J, Parekh U, Dhar P, Wang M, Hulse M, *et al.* A quality improvement project to reduce hypothermia in infants undergoing MRI scanning. *Pediatr Radiol* 2016;46:1187-98.
- Roth JV, Braitman LE. Nasal temperature can be used as a reliable surrogate measure of core temperature. *J Clin Monit Comput* 2008;22:309-14.
- Duggappa AK, Mathew S, Gupta DN, Muhamed S, Nanjangud P, Kordcal AR. Comparison of nasopharyngeal temperature measured at fossa of Rosenmuller and blindly inserted temperature probe with esophageal temperature: A cross-sectional study. *Anesth Essays Res* 2018;12:506-11.
- Muma BK, Treloar DJ, Wurmlinger K, Peterson E, Vitae A. Comparison of rectal, axillary, and tympanic membrane temperatures in infants and young children. *Ann Emerg Med* 1991;20:41-4.

17. McCaffrey TV, Geis GS, Chung JM, Wurster RD. Effect of isolated head heating and cooling on sweating in man. *Aviat Space Environ Med* 1975;46:1353-7.
18. Snoek AP, Saffer E. Agreement between lower esophageal and nasopharyngeal temperatures in children ventilated with an endotracheal tube with leak. *Pediatr Anesth* 2016;26:213-20.

New features on the journal's website

Optimized content for mobile and hand-held devices

HTML pages have been optimized for mobile and other hand-held devices (such as iPad, Kindle, iPod) for faster browsing speed.

Click on **[Mobile Full text]** from Table of Contents page.

This is a simple HTML version for faster download on mobiles (if viewed on desktop, it will be automatically redirected to full HTML version)

E-Pub for hand-held devices

EPUB is an open e-book standard recommended by The International Digital Publishing Forum which is designed for reflowable content i.e. the text display can be optimized for a particular display device.

Click on **[EPub]** from Table of Contents page.

There are various e-Pub readers such as for Windows: Digital Editions, OS X: Calibre/Bookworm, iPhone/iPod Touch/iPad: Stanza, and Linux: Calibre/Bookworm.

E-Book for desktop

One can also see the entire issue as printed here in a 'flip book' version on desktops.

Links are available from Current Issue as well as Archives pages.

Click on  View as eBook