Clinical Investigation

Anatomic features of the neck as predictive markers of difficult direct laryngoscopy in men and women: A prospective study

Address for correspondence:
Dr. Chryssoula Staikou, Department of Anaesthesiology, Aretaieio Hospital, Medical School, University of Athens, 76 Vassilissis. Sophias Av., 11528, Athens, Greece.
E-mail: c_staikou@yahoo.gr

Liaskou Chara, Vouzounerakis Eleftherios[1], Moirasgenti Maria[2], Trikoupi Anastasia[3], Staikou Chryssoula[4]

Department of Anaesthesiology, General Hospital of Rethymnon, Rethymnon, Crete, [1]Department of Internal Medicine, George Papanikolaou General Hospital, Exohi, Thessaloniki, [2]Intensive Care Unit, University General Hospital "AHEPA", [3]Department of Anaesthesiology, George Papanikolaou General Hospital, Exohi, Thessaloniki, [4]Department of Anaesthesiology, Aretaieion Hospital, School of Medicine, Athens, Greece

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ABSTRACT

Background and Aims: Difficult airway assessment is based on various anatomic parameters of upper airway, much of it being concentrated on oral cavity and the pharyngeal structures. The diagnostic value of tests based on neck anatomy in predicting difficult laryngoscopy was assessed in this prospective, open cohort study. **Methods:** We studied 341 adult patients scheduled to receive general anaesthesia. Thyromental distance (TMD), sternomental distance (STMD), ratio of height to thyromental distance (RHTMD) and neck circumference (NC) were measured pre-operatively. The laryngoscopic view was classified according to the Cormack–Lehane Grade (1-4). Difficult laryngoscopy was defined as Cormack–Lehane Grade 3 or 4. The optimal cut-off points for each variable were identified by using receiver operating characteristic analysis. Sensitivity, specificity and positive predictive value and negative predictive value (NPV) were calculated for each test. Multivariate analysis with logistic regression, including all variables, was used to create a predictive model. Comparisons between genders were also performed. **Results:** Laryngoscopy was difficult in 12.6% of the patients. The cut-off values were: TMD ≤7 cm, STMD ≤15 cm, RHTMD >18.4 and NC >37.5 cm. The RHTMD had the highest sensitivity (88.4%) and NPV (95.2%), while TMD had the highest specificity (83.9%). The area under curve (AUC) for the TMD, STMD, RHTMD and NC was 0.63, 0.64, 0.62 and 0.54, respectively. The predictive model exhibited a higher and statistically significant diagnostic accuracy (AUC: 0.68, $P < 0.001$). Gender-specific cut-off points improved the predictive accuracy of NC in women (AUC: 0.65). **Conclusions:** The TMD, STMD, RHTMD and NC were found to be poor single predictors of difficult laryngoscopy, while a model including all four variables had a significant predictive accuracy. Among the studied tests, gender-specific cut-off points should be used for NC.

Key words: Height-to-thyromental distance ratio, laryngoscopy, neck circumference, sternomental distance, thyromental distance

INTRODUCTION

Difficult airway is a potentially catastrophic incident,[1] as it may result in airway or oesophageal injury, aspiration and severe hypoxaemia with consequent brain damage and/or death. Although oxygenation/ventilation - via various devices - is always the primary goal in the management of a difficult airway, tracheal intubation remains the gold standard in securing the airway; it ensures optimal ventilation and oxygenation while protecting the respiratory tract from aspiration.

In a large retrospective study of more than 15,000 cases, the incidence of failed intubation was 1/2230 in surgical

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patients and 1/283 in the obstetric population.[2] The difficulty of tracheal intubation has been strongly related with the direct laryngoscopic view, as classified by Cormack and Lehane (grades 1-4).[3] In most studies, laryngoscopy and subsequent intubation are considered difficult in patients with a laryngoscopic view of Cormack–Lehane grade 3 or 4.[4] The reported incidence of difficult direct laryngoscopy ranges between 1.5% and 8.5% in patients receiving general anaesthesia.[5] In a meta-analysis of Shiga *et al*., including 35 studies with a total of 50,760 patients without pathologic airway anatomy, the incidence of difficult intubation - defined as Cormack–Lehane grade ≥3 - was 5.8% for the overall patient population.[4]

Several bedside screening tests - with the most popular being the Mallampati classification, mouth opening, thyromental distance, upper lip bite and head–neck mobility - have been used in clinical practice for predicting the difficult laryngoscopy/intubation.[6-9] Even though they are quite simple, most of them require patient's cooperation in order to be performed properly and thus assessed correctly.

The aim of the present study was to evaluate certain anatomic features of the neck that can be measured pre-operatively with minimal patient cooperation and to assess their diagnostic value in predicting difficult direct laryngoscopy.

METHODS

The study was approved by the Institutional Review Board and was conducted between March 1 and June 30 2011. Three hundred and eighty-seven (387) consecutive adult patients (age >18 years) ASA I–II, without known airway pathology, scheduled for surgical procedures under general anaesthesia with tracheal intubation were assessed for eligibility to be included in this prospective, open cohort study. Forty-six patients were excluded due to one or more of the following exclusion criteria: Obvious airway malformations, need for rapid sequence induction/intubation under cricoid pressure (obstetric cases included) or awake intubation, cervical spine pathology requiring specific manipulation and severe obesity (body mass index [BMI] more than 35 kg/m^2). Finally, 341 patients were included in the study after obtaining their written informed consent to participate.

Pre-operative measurements of the thyromental distance (TMD), sternomental distance (STMD), ratio of height to thyromental distance (RHTMD) and neck circumference (NC) were performed in all patients by the same investigator (C.L.) using a measuring tape. The TMD was defined as the straight-line distance (cm) from the lower border of the thyroid notch to the bony point of the mentum, with the head extended and the mouth closed.[10,11] The STMD was defined as the straight line distance (cm) from the bony point of the mentum to the upper border of the manubrium sterni, with the head extended and the mouth closed.[12] The NC was measured at the level of the thyroid cartilage with the head in a neutral position.[13] Each patient's height was also recorded in order to calculate the RHTMD.[14]

In the operating room, standard monitoring was applied to every patient (electrocardiograph, pulse oximeter and non-invasive blood pressure measurement) and a vein catheter was inserted for fluid and drug administration. After pre-oxygenation with 100% oxygen for 3 min, anaesthesia was induced with propofol 2.5 mg/kg and fentanyl 2 μg/kg. Rocuronium 1 mg/kg was given to facilitate tracheal intubation (after 90 s) with the patient's head in the "sniffing position". Direct laryngoscopy was performed with a Macintosh blade by a senior anaesthesiologist not apprised of the pre-operative measurements. The size of the laryngoscopic blade was chosen according to the patient's size (size 3 for medium- and size 4 for large-sized adults) and the responsible anaesthesiologist's clinical judgment. Seven anaesthesiologists with a clinical experience of ≥7 years were involved. The laryngoscopic view was classified according to the Cormack–Lehane grade[3]: Difficult laryngoscopy was defined as inadequate exposure of the glottis (Cormack–Lehane grade 3 or 4) under direct laryngoscopy with a blade of appropriate length, without any external pressure or other manoeuvre applied.

The predictive value of the tests (TMD, STMD, RHTMD and NC) for difficult laryngoscopy was assessed: Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated for each variable. Sensitivity reflects the proportion of difficult tracheal intubations correctly predicted to be difficult, specificity shows the proportion of easy tracheal intubations correctly predicted to be easy, PPV is the proportion of predicted difficult intubations that actually proved to be difficult and NPV is the proportion of predicted easy intubations that actually proved to be easy. In addition, receiver

operating characteristic (ROC) curves were used to identify the optimal cut-off point of each variable and the area under curve (AUC) was calculated to assess the prognostic accuracy of each test. Comparisons between men and women were made regarding the incidence of difficult intubation and also the values and optimal cut-off points of the studied variables. Finally, multivariate analysis with logistic regression, including TMD, STMD, RHTMD and NC, was used to create a model predicting difficult laryngoscopy. The Hosmer–Lemeshow test was used to assess the goodness of fit in the risk prediction model.

Our hypothesis was that the anatomic features of the neck may be useful predictive markers of difficult laryngoscopy. The primary end-point of the study was the diagnostic value of TMD, STMD, RHTMD, NC and of a model including all four variables in predicting a Cormack–Lehane grade ≥3. Secondary end-points were differences between the genders regarding the optimal cut-off points and the accuracy of the studied tests with the use of gender-specific cut-off points.

The sample size of our study was based on the meta-analysis of Shiga *et al.*, who reported a 5.8% (4.7-7.5%) incidence of Cormack–Lehane grade 3 or 4 in 50,760 patients without airway deformities.[4] The necessary sample size was estimated for a 95% confidence interval (CI) by the use of the Epi Info statistical package (version 6): At least 219 patients needed be included in the study. Statistical analysis was performed using the SPSS Software (version 18) and Med Calc (version 10). Variables were tested for normality of distribution with the Kolmogorov–Smirnov test. The Mann–Whitney test was used for comparisons of Cormack–Lehane grade, TMD, STMD, RHTMD and NC between men and women. The incidence of Cormack–Lehane grade ≥3 among the seven anaesthetists who performed the laryngoscopies was compared by the use of the X^2 test.

RESULTS

Data from 341 patients were analyzed. Demographic features and the Cormack–Lehane laryngoscopic view of the studied population are presented in Table 1. Regarding the dental condition of the patients, 45 of them (13.2%) had removable dentures (partial or complete, upper or lower), but none was completely edentulous or had dental braces or significantly protruding teeth. There was no change of the laryngoscopic blade size in any of the cases. The laryngoscopy was assessed as difficult (Cormack–Lehane grades 3 and 4) in 43 (12.6%) of the studied patients. The incidence of Cormack–Lehane grades 3 and 4 in the laryngoscopies performed by the seven anaesthesiologists did not differ statistically among them (X^2 = 6.884, P = 0.142). There were no failed tracheal intubations. In 329 patients (96.5%), intubation was achieved at the first attempt and in 12 patients (3.5%), at the second attempt, after application of external manoeuvres and/or use of a gum elastic bougie. No other intubation aids were used.

The mean values (SD; 95% CI) of the measured variables were TMD: 8.6 (1.4; 8.4-8.7) cm, STMD: 17.2 (2.3; 17-17.4) cm, RHTMD: 20.2 (3.1; 19.9-20.5) and NC: 38.7 (4.7; 38.2-39.2) cm. The ROC curves of the studied variables are shown in Figure 1. The optimal cut-off points, sensitivity, specificity, PPV, NPV and AUC for each test are presented in Table 2. The RHTMD had the highest sensitivity and NPV. All tests had a low PPV and a high NPV. A statistical

Table 1: Patients' characteristics and laryngoscopic view according to the Cormack and Lehane grade

Patient characteristics	Value: (mean±SD) or *n* (%)
Gender: Male/female	163 (47.8)/178 (52.2)
Age (years)	50±18
Height (cm)	169±9
Body weight (kg)	75±15
BMI (kg/m^2)	26±4
Cormack-Lehane grade 1	231 (67.74)
Cormack-Lehane grade 2	67 (19.65)
Cormack-Lehane grade 3	32 (9.38)
Cormack-Lehane grade 4	11 (3.23)

SD – Standard deviation. Values are expressed as mean±SD or as *n* (%)

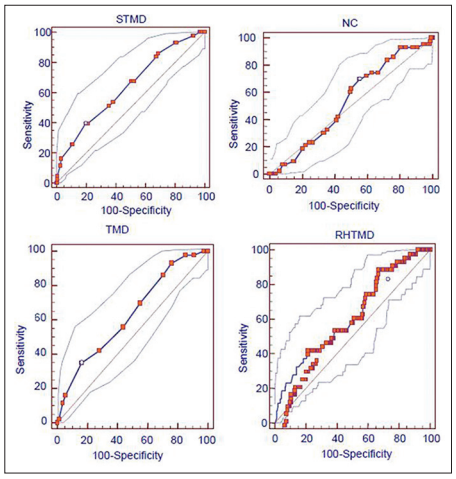

Figure 1: Receiver operating characteristic curves for the four studied screening tests for difficult laryngoscopy in the whole sample: Thyromental distance (TMD), sternomental distance (STMD), ratio of height to thyromental distance (RHTMD) and neck circumference (NC)

Table 2: The cut-off points and measures of diagnostic accuracy in the whole sample and each gender regarding the thyromental distance, sternomental distance, ratio of height to thyromental distance and neck circumference

Predictive test	Cut-off value	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AUC mean (95% CI)	*P*
Whole sample (males+females)							
TMD (cm)	≤7	34.9	83.9	23.8	89.9	0.63 (0.57-0.68)	0.0039*
STMD (cm)	≤15	39.5	80.2	22.4	90.2	0.64 (0.58-0.69)	0.0023*
RHTMD	>18.4	88.4	33.2	16	95.2	0.62 (0.57-0.67)	0.0095*
NC (cm)	>37.5	69.8	44.6	15.4	91.1	0.54 (0.48-0.59)	0.3948
Males							
TMD (cm)	≤9.5‡	89.5	32.6	14.9	95.9	0.63 (0.55-0.70)	0.05
STMD (cm)	≤18‡	84.2	39.6	15.5	95	0.65 (0.57-0.72)	0.02*
RHTMD	>18.4	84.2	38.9	15.4	94.9	0.62 (0.54-0.69)	0.09
NC (cm)	≥39‡	31.6	77.1	15.4	89.5	0.53 (0.45-0.61)	0.64
Females							
TMD (cm)	≤7	45.8	75.3	22.4	89.9	0.62 (0.54-0.69)	0.05
STMD (cm)	≤15	45.8	76	22.9	90	0.62 (0.55-0.70)	0.05
RHTMD	>22.3‡	45.8	75.3	22.4	90	0.61 (0.53-0.68)	0.08
NC (cm)	>37.5	54.2	77.3	27.1	91.5	0.65 (0.58-0.72)	0.02*

*Statistical significance for *P*<0.05. ‡Different cut-off point in the specific-gender compared with the total population studied. TMD – Thyromental distance, STMD – Sternomental distance, RHTMD – Ratio of height to thyromental distance and NC – Neck circumference, PPV – Positive predictive value, NPV – Negative predictive value, AUC – Area under curve indicating the diagnostic accuracy of each test

significance ($P < 0.05$) was found for the diagnostic accuracy of TMD, STMD and RHTMD.

Comparisons between men and women showed no significant difference regarding the incidence of difficult intubation ($P > 0.05$) and Cormack–Lehane grade ($P > 0.05$). On the other hand, the studied variables were found to differ significantly: The median values in men/women were, for TMD: 9/8 cm ($P < 0.001$), for STMD: 18/17 cm ($P = 0.003$), for RHTMD: 19.2/20.4 ($P = 0.009$) and for NC: 41/36 cm ($P < 0.001$). The optimal cut-off points also differed between the genders, as shown in Table 2. A statistically significant predictive accuracy was found for STMD in males and for NC in females ($P = 0.02$).

In multivariate analysis, the logistic regression model incorporating all the studied variables (TMD, STMD, RHTMD, NC) and the optimal cut-off points from the ROC curves were used. The Hosmer–Lemeshow test indicated a good logistic regression model fit ($P = 0.35 > 0.05$). The inclusion of TMD, STMD, RHTMD and NC improved the prognostic value of the model (x^2 (4) =15.97, $P = 0.003 < 0.05$), although none of the variables was significant as an independent prognostic factor ($P > 0.05$). The ROC curve of the risk model describes the screening characteristics of the model: At any given point along the line, the trade-off between sensitivity and specificity can be observed [Figure 2]. The AUC was found to be 0.68 (CI: 0.63-0.73, $P < 0.001$), denoting that the model had a statistically significant diagnostic accuracy, higher than that of each test alone. The sensitivity and specificity of the logistic regression model were 74.4% (58.8-86.5%, 95% CI) and 53% (47.2-58.9%, 95% CI) accordingly (optimal cut-off value >0.13).

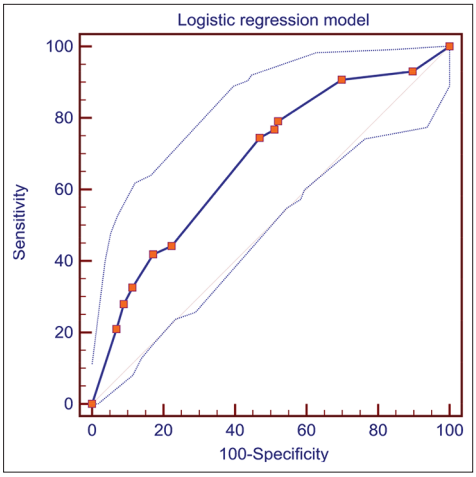

Figure 2: Receiver operating characteristic curve of the logistic regression model incorporating the thyromental distance (TMD), sternomental distance (STMD), ratio of height to thyromental distance (RHTMD) and neck circumference (NC) in the whole sample

DISCUSSION

We found that a model including TMD, STMD, RHTMD and NC had a significant predictive accuracy for difficult laryngoscopy. Among the studied tests, the RHTMD had the highest sensitivity and the highest NPV, while TMD had the highest specificity and PPV. Except for RHTMD, the rest of the tests had a low sensitivity, while all of them had a low PPV and a high NPV, in agreement with the existing literature.[15] Theoretically, a perfect predictor is

characterised by high sensitivity and high specificity; thus, a high diagnostic accuracy, in order to identify almost every patient at risk with minimal false positive predictions. In clinical practice, anaesthesiologists are mostly concerned for the unanticipated difficult airway (false negative predictions), which may find them unprepared. On the other hand, false positive predictions, although disturbing, distressing and inconvenient, have no life-threatening sequelae. Consequently, the most significant clinical problem is the false negative predictions; thus, intubations predicted to be easy, proved to be difficult later. Sensitivity and NPV are statistical measures of a test performance incorporating the false negative predictions in their calculation formula. Among the tests studied, the above-mentioned characteristics apply best to RHTMD as a single predictor of difficult laryngoscopy.

The incidence of difficult laryngoscopy did not differ between men and women; but, it was relatively high,[4] possibly because the laryngoscopic view was assessed without application of any external manoeuvres. Nevertheless, similarly high frequencies of difficult laryngoscopy - exceeding 10% - have been reported by other investigators as well.[15-17]

The optimal cut-off point we found for TMD in the whole sample is similar to that reported in previous studies.[18,19] Nonetheless, such morphometric measurements may be affected by racial characteristics, and small differences in cut-off points are found among studies conducted in different populations.[15,20] Also, TMD has been found to be both sex and age dependent,[21] while some investigators have used different cut-off points in males and females.[22] In line with these, we also found that TMD values and cut-off points differed significantly between the genders. Nevertheless, the use of different cut-off points in men and women did not improve the predictive accuracy of the test. Furthermore, in accordance with previous results,[15,18,23] we also found that TMD is a poor predictor of difficult laryngoscopy. Our results confirm the suggestion of other investigators[24,25] that TMD is not accurate enough to be used as a sole predictive test of difficult laryngoscopy.

The mean value and optimal cut-off point of STMD in our studied sample are similar to those reported by Kim *et al*. in Korean patients.[12] On the other hand, lower cut-off points (13-13.5 cm) were calculated or used in other studies.[7,8] As with TMD, the different racial characteristics may – at least partly - account for the different results. Notably, we also found significant differences in STMD values and cut-off points between the genders. The use of the gender-specific cut-off points resulted in a higher – but still poor - predictive accuracy of STMD in men. Despite population- and gender-related differences, our findings indicate that the STMD is a test of limited predictive accuracy when used alone, as reported by other investigators as well.[7,8,12]

The best cut-off point for RHTMD in the whole sample and also in male patients was lower than the previously reported values (21-25).[14,15,26] On the other hand, the optimal cut-off value in women was in the aforementioned range.[14,15,26] Because RHTMD is height dependent, the significant differences in height among races probably account for the different values reported in the literature with regard to diagnostic accuracy; the RHTMD was not found to be superior to the other studied parameters according to the AUC. Also, the use of different cut-off points in males and females did not improve the predictive accuracy of the test in either gender and thus offered no benefit. Compared with the other tests, we found that RHTMD was the most sensitive in predicting difficult laryngoscopy, but had a low specificity and PPV. Similar findings regarding the predictive value of the test have been reported by other investigators too.[15,16,26-28] The RHTMD has been found to be comparable with the upper lip bite test[26] in predicting difficult intubation, and superior to the modified Mallampati test,[15,26] TMD, mouth opening and neck movement.[15]

Neck circumference had a low sensitivity in predicting difficult laryngoscopy in the population studied. The mean NC value of our patients was similar to that described by Gonzalez *et al.*, who studied patients with a BMI below and above 30 kg/m^2, and found mean NC values of 39 and 42 cm, respectively.[29] Interestingly, these investigators also found that a circumference over 43 cm was independently correlated with difficult intubation in both populations, with a sensitivity of 92%.[29] On the other hand, NC has been mostly studied in severely obese patients (BMI > 35 kg/m^2), and different values have been reported there; Brodsky *et al*. studied patients with a BMI > 40 kg/m^2 and found that NC was a significant predictor of difficult intubation.[13] For a circumference of 40 cm, the probability of a difficult intubation was approximately 5%, while the probability increased up to 35% at a NC of 60 cm.[13]

The odds increased by 1.13 times when NC increased by 1 cm.[13] Yet, it is not only the circumference but also the amount of pre-tracheal soft tissue that matters, as demonstrated in obese patients by the use of ultrasound.[30] Furthermore, gender-related anatomic differences may be significant; in our study, men had a significantly larger neck circumference than women, and similar findings have been reported by Brodsky *et al*.[13] Moreover, in our study, the predictive accuracy of NC was significantly improved in women when a different, gender-specific cut-off point was used. All the above probably justify the suggestion that it would be more appropriate to use different NC cut-off points in men and women.[31]

According to the existing literature, the bedside tests are considered poor predictors of difficult intubation, especially if each of them is used alone.[4,32] Based on the AUC, we also found a relatively poor diagnostic accuracy for the TMD, STMD, RHTMD and NC. Interestingly, we found that the predictive accuracy of these tests - with the exception of NC - was not improved by the use of gender-specific cut-off points. The model incorporating all four variables achieved a moderate to fair diagnostic accuracy, which – as expected - was higher than each test alone.

In clinical practice, our findings may be applicable in patients who – due to mental or physical disability - cannot cooperate adequately or are unable to perform properly other tests such as the Mallampati and upper lip bite tests. Although the latter tests are probably more accurate or better validated, they require the patient's cooperation. On the other hand, the predictive tests we used are actually measurements performed with the patient's head in a neutral or extension position, which may be achieved even passively in incapable patients. It should also be noted that the variables we studied exhibit better inter-observer reproducibility than other tests, such as head–neck mobility, which are characterised by high inter-rater variability and thus reduced predictive reliability,[33] especially in poorly cooperating patients. In the present study, in order to eliminate any bias from inter-observer variability, a single investigator performed all the pre-operative measurements.

A limitation of the study is that laryngoscopy was undertaken by different anaesthesiologists. Nevertheless, only experienced anaesthetists were involved in order to limit the possibility of systematic error in our results. Furthermore, the incidence of difficult laryngoscopies was comparable among them. Another limitation of the study, although inevitable in studies investigating anthropometric features, is that possibly our results should be interpreted and extrapolated with caution to populations with significantly different morphological characteristics.

CONCLUSION

The studied anatomic features of the neck: TMD, STMD, RHTMD and NC, were found to be relatively poor single predictors of difficult laryngoscopy. Among the tests, gender-specific cut-off points should be used for NC as they improved its diagnostic accuracy. Finally, a model including all four variables exhibited a statistically significant predictive accuracy, and may possibly represent a helpful alternative in patients unable to perform properly the other tests that require patient cooperation.

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Announcement

CALENDAR OF EVENTS OF ISA - 2014

Certain important dates are given here for the members. All the applications should be sent by registered post (with Acknowledgement Due)

Date	Name of the Award/Post	Application has to be sent to
30th June 2014	Bhopal Award for Academic Excellence	Hony. Secretary, ISA
15th August 2014	Prof. A. P. Singhal Life Time Achievement Award	Hony. Secretary, ISA
31st October 2014	Dr. (Mrs.) Rukmini Pandit Award - Publication format along with Conference Presentation Certificate	Hony. Secretary, ISA
31st October 2014	Y. G. Bhoj Raj Award - Best Review Article in IJA	Hony. Secretary, ISA
31st October 2014	Dr. Kop's Award	Chairman Scientific committee of ISACON with a copy to Hony Secretary ISA
27th November 2014	Dr. TN Jha Memorial & Dr. KP Chansoriya Travel grant	Hony. Secretary, ISA
27th November 2014	Late Dr. Venkata Rao Memorial Oration	Hony. Secretary, ISA
27th November 2014	Ish Narani Best Poster Award	Chairman Scientific Committee ISACON
28th November 2014	ISA GOLDCON QUIZ Competition	Chairman Scientific Committee ISACON
28th November 2014	Awards for 1. Best City Branch 2. Best State Branch 3. Best Metro Branch 4. Public Awarness Individual 5. Public Awarness City 6. Public Awarness State 7. Ether Day State 8. Ether Day City 9. Membership Drive % (State) 10. Membership Drive No.s (State) 11. Individual Drive	Hony. Secretary, ISA

Dr. M V Bhimeshwar
Hon. Secretary - ISA,
Mobile – 098480 40868 Phone - 040 - 2717 8858
Email: isanhq@isaweb.in
Website: www.isaweb.in