Volume 12, Issue 4, Oct - Dec, 2020

REVIEW	
The impact of human resource and quality management in health care: A Review VEVITA PRIYA, , DR. C. VENKATESWARAN	⊹ ⊚
Phytochemical and Pharmacological Potential of Plant Pimenta dioica Linn. KOMALA M, VIPUL V. DHASADE	*
COVID: an Overview of Their structure, Replication, diagnosis, drug targets, new reported drugs and vaccine strategy NAGARAJU BANDARU, UMA SANKAR GORLA, Y.KRANTHI, GSN KOTESWERRAO, A.ANKARAO	*
An Overview on Floating Microsphere RAGHAV MISHRA, ACHYUT MISHRA	¥
A systematic review of promoting and support successful breastfeeding AYU PRAMBANDARI, MUFDLILAH	*
Basaloid Squamous Cell Carcinoma of the Oropharynx - Brief Overview SRIKUMAR CHAKRAVARTHI, BARANI KARIKALAN	*
A Study on the Impact of Climate Change on the Multigenerational Migration Journey of Monarch Butterflies K. YAMUNA, S.N. JYOTHI, GEVARGIS MURAMTHOOKIL THOMAS, SHILPA HARI PRAKASH, GOURI S NAIR	⊹ ∘
Biodiesel production from wastewater as a source using microorganisms: A review C GIRISH,	*
Nanocarrier of Solid Lipid a Colloidal Disperse System for Drug Delivery HAYDER DRAIS, AHMED ABBAS HUSSEIN, MOWAFAQ MOHAMMED GHAREEB	*
Pharmacological Review Of Portulaca Grandiflora Hook DEVI M., HARIKRISHNAN N., RAMYA M., NANDHINI M.	*
HPLC and its uses in current era- A review REETHEGA.L , BRUNDHA.M.P, GEETHA.R.V	*
Assessment of Tooth with Primary Periodontal Lesion Requiring Endodontic Therapy: A Retrospective Analysis SHREYA SVITLANA, RAGHU SANDHYA, JAIGANESH RAMAMURTHY	*
Effect of Maternal Occupation in Orofacial Clefts ADITYA REDDY.P, ABDUL WAHAB P U, JAGADISH V	*
Evaluating The Number Of Walls Present And Its Significance On The Teeth Restored With Prefabricated	*

How is the Application of Family Center Care in Children with Cancer: A Literature Review? SUMARTI ENDAH PURNAMANINGSIH MARIA MARGARETHA, CHRISTANTIE EFFENDY, SRI MULATSIH, HARI KUSNANTO	*
Literature Review of Orofacial Muscle Contraction Detection Tool in Children HARUN ACHMAD, EVGENIY V. KIRICHENKO, EVAYANTI AKE	*
Differential Diagnosis of Lymphadenopathies SEIDALIN N.K., BENBERIN V.V., SHANAZAROV N.A, TULEUBAEVIA A.A, SATAEVA ?.S, TOKHPANOVA N.A, ISABEKOVA A.M	*
Comparison of sitting calisthenics vs respiratory muscle stretch gymnastics to desensitize dyspnea in moderate COPD patients D. ANANDHI	*
Comparison between physical training and multisensory training on balance among diabetic peripheral neuropathy patients POOJA KUMARI MAHASETH, J. SURESH	*
Review on Understanding Drug dosage Regimens and its Design-The First-step Towards Rational Prescribing PRASAATH SASTHA.K.R, RAMALINGAM KOTHAI, KATHIRVEL. R, BALASUBRAMANIAN ARUL	҂
White Spot Lesions In Orthodontic - A Literature Review HEMASHREE J, RAVINDRA KUMAR JAIN	*
Usefulness Of T-Scan In Orthognathic Surgery: Literature Review R RAJASHRI, M P SANTHOSH KUMAR	*
Effect Of Farnesol On Oral Pathogens- A Systematic	
Review SRUJANA HEMMANUR, IFFAT NASIM	*
	* *
SRUJANA HEMMANUR, IFFAT NASIM Comparison of the Effectiveness of Ciprofloxacin Drops with Levofloxacin Drops in Patients with Chronic Suppurative Otitis Media (CSOM) between 2016-2019	·
SRUJANA HEMMANUR, IFFAT NASIM Comparison of the Effectiveness of Ciprofloxacin Drops with Levofloxacin Drops in Patients with Chronic Suppurative Otitis Media (CSOM) between 2016-2019 GHOLAM-ALI DASHTI KHAVIDAKI, REZA GHARIBI Excipient profile and future possibilities of fucoidan: a review	*

Fiber Post In Single Rooted Teeth In Both Upper And Lower Arches -A Retrospective Study KEERTHIKA .R, SURENDAR SUGUMARAN	
Nano Based Dental Preparation - An Update N.E. KAVIYA, ANITHA ROY	
Comparison of the Effectiveness of Using Bovine and Human Dry Amniotic Membrane based on Mucosal Integrity in Urethral Defect Reconstruction: Experimental Study on New Zealand Rabbits FRANKLIN MALONDA, I.G.B.ADRIA HARIASTAWA, ETTY HARY KUSUMASTUTI, EDWIN DANARDONO	
Outcomes of Patients with Chronic Lymphocytic Leukemia Treated with Chemotherapy in Middle Euphrates Region of Iraq: Data from Developing Country AHMED MJALI, ZAHRAA KADHIM HASAN, KARRAR KADHIM MOHSIN	b
Biological Characteristics and Causes of Degradation of Rats Mandibular Condylar Cartilage AMEERA KHALEEL, DR. RAMIZU BIN SHAARI, DR. MOHAMAD ARIF AWANG NAWI, DR.ALI SULTAN ALRIFAI	•
Comparative Diagnostic Value of Anti-Dengue IgG, Anti-Dengue IgM of Two Rapid Tests in Dengue Virus Infection MAY TANZILIA, NELLY ZUROIDAH, I GUSTI AGUNG AYU EKA PUTRI SUNARI, BILLY JORDAN WRAHATNALA, FARADILA KHOIRUN NISA, HAKIM, ALI ROHMAN, PUSPA WARDHANI, DOMINICUS HUSADA, SITI NADIA TARMIZI, ARYATI	•
Skeletal Deformities of Children with Cerebral Palsy (Clinicoepidemilogical Study) DR.ALI HASSAN	Ð
Data Access Controls in Cloud: A Survey YOGESH M.GAJMAL, R.UDAYAKUMAR ★	
Anti-Hypertensive treatment guidelines, result and their evaluation SHAIK ALI, DR MAHAVEER SINGH, DR BIRENDRA SHRIVASTAVA, DR KONDA RAVI KUMAR, DR MADAN MOHAN GUPTA	Đ
Assessment of patients visited for management of oral cancer in a private dental institution - a retrospective study DINESH PRABU.M	Þ
Oral Health in Down Syndrome - A Literature Review NUR HANNAH, MAHESH RAMAKRISHNAN)
A systematic review of medicinal plants used in Nigeria for hypertension management, OKUKWE CHRISTA OBODE, ABIODUN HUMPHREY ADEBAYO, CONRAD ASOTIE OMONHINMIN, OMOLARA FAITH YAKUBU	3

Periodontal considerations for denture placement: A literature review ARNI IRAWATY DJAIS, SRI OKTAWATI, HARUN ACHMAD, ERI HENDRA JUBHARI, SHINTA RAHMA M., FIRMAN SALAM, NUR MASYTA S., DANIEL TETAN-EL	*
Gingival Mask as A Non-Surgical Treatment in Gingival Recession: A Literature Review SRI OKTAWATI, ARNI IRAWATY DJAIS, HARUN ACHMAD, ERI HENDRA JUBHARI, NUR MASYTA S., SHINTA RAHMA M., ALFRIDA PASANGALLO, ADHAWANTY	*
Bone Augmentation Procedure Before Placing the Dental Implant: A Literature Review SRI OKTAWATI, ARNI IRAWATY DJAIS, HARUN ACHMAD, ERI HENDRA JUBHARI, RACHMI BACHTIAR, SHINTA RAHMA M., FIRMAN SALAM	*
A Review on Antiangiogenic Activity Medicinal Plants Available in Iraq OMAR HUSSEIN AHMED, AMJED HASEEB KHAMEES, SHATHEL KHALAF NOMAN	*
Animals Mentioned In The Islam's Prophetic Traditions: A Review Of The Scientific Evidence ISMAIL FAHMI ARRAUF NASUTION, ABDUL MUFID, KISNO, MUHAMMAR AMIN, IMAM JAYANTO, SOLIHAH TITIN SUMANTI, SUKARDIN, WAHID WACHYU ADI WINARTO, M. FADLI, MIKSUSANTI, ARIEF MUAMMAR, AHMAD TOHIR, AMIE PRIMARNI, ISKANDAR, IMAM ALI BASHORI	*
Mental Health Consequence Of COVID 19 Pandemic Among Health Care Workers: Systematic Review MEHNAZ ZAFAR, FATMA MAGDI	*
Factors Associated with Positive Life Assets in Adolescents: An Integrative Literature Review WANICH SUKSATAN, BOVORNPOT CHOOMPUNUCH, VACHIRA POSAI	*
Role Of Dental Pulp Stem Cells In Restoring Vision- Narrative Review NEETHU ANN PREETHY P, AHSANA.A, DR.DEEPA GURUNATHAN, DR.LAKSHMI.T	*
A Histological Review on Raktadhara Kala and Raktavah Strotas and Its Modern Correlation , DR ANNU CHAUHAN, DR AJITKUMAR S WAHANE, DR MANEELA SHARMA	ıa
Oral Pulsatile Drug Delivery System- A Review SYED GOUSE FIROZ, R.KOTHAI, B.ARUL	*
A Comprehensive review on Commiphora caudata (Wigh &Arn). P. SRINIVASAN, R. KOTHAI, B.ARUL	nt
Hepatocellular Carcinoma-A Mini Review R. VENKATESWARARAO, R.KOTHAI, B.ARUL	

Microalgae-based Microbial Fuel Cells: A Review VAANIE GODBOLE, MANOJ KUMAR PAL, PANKAJ GAUTAM A Review on Face mask and its potential in preventing viral infections
REKHA GOSWAMI, ABHILASHA MISHRA, ANUP MISHRA

Removal of persistent and toxic Organochlorine pesticide using metallic nanomaterials from water: A review PRIYANKA GUPTA

RESEARCH	
Life review of elderly depression DWI ROCHMAWATI, BETIE FEBRIANA, WIWIT RIZKI, YASINTA AMALI	*
Development and application of ATR-FTIR spectroscopy for mixture homogeneity in pharmaceutical application SYAIFUL CHOIRI, TEUKU NANDA SAIFULLAH SULAIMAN, ABDUL ROHMAN	*
The Increasing Damage in Tubular Cell of Infant Mice's Kidneys from Carbofuran Exposure during its Mothers' Lactation Period EDI PURNOMO, WIDJIATI, HERMIN RATNANI, EPY MUHAMMAD LUQMAN	*
Trend of transsexualism problem and its implications towards muslim community in Malaysia WAN IZZATI, WAN MOHD KHAIRUL FIRDAUS WAN KHAIRULDIN, ABDUL HANIS EMBONG, HASANULDDIN MOHD, WAN KHAIRUL AIMAN WAN MOKHTAR	*
Development and validation of RP-HPLC method for the estimation of pidotimod in tablet dosage form GAYATRI GAGE, MITHUN RUDRAPAL, ANIL G. JADHAV, ATUL R. BENDALE, LAXMIKANT B. BORSE	*
Evaluation of neurotoxicity of the ethanolic bark extract of Holarrhena pubescens Wall. ex G.Don in mice SANJIT NAMASUDRA, PANKAJ PHUKAN, MEENAKSHI BAWARI	*
Design, synthesis and evaluation of 2-aminobenzimidazole derivatives: strong candidate for PPAR gamma agonists. ANTON.SMITH.A, MATHAN.S, SUNILKUMAR. D	*
Prediction of Heart Disease Using Feature Selection and Random Forest Ensemble Method DHYAN YADAV, SAURABH PAL	*
Strategies for Antiviral Drugs from Plants by Targeting the Hemagglutinin, Neuraminidase and other receptors of Influenza A virus SONU BANSAL, G. SIBI	*
Drug-related problems among chronic kidney disease patients: a clinical pharmacist led study DANIEL ROY, IBRAHIM SHANFAR, PRADEEP SHENOY, SHARAD CHAND, NANDAKUMAR UP, BHARATH RAJ KC	*
Ethnopharmacology and drug development SOUGATA SARKAR, VARTIKA SRIVASTAVA	•
Formulation and evaluation solid dispersion based fast dispersible tablets of domperidone	¥

Ī	KUSHAL NATH, SHAMBADITYA GOSWAMI	
	A New Paradigm Shift in Formulation Development by Smart Drug Delivery System ALANKAR SHRIVASTAVA	*
	Removal of Heavy Metals from Pharmaceutical Wastewater by Adsorption using Agricultural Waste: A Review C GIRISH	*
	Covid-19 A New Global Outbreak: Diagnosis, Treatment and Prevention AMIT KUMAR, AAKANSHA GOSWAMI, VIKRANT VERMA	*
	Similar Biologics: Current Summary and Future Outlook ABHISHEK KERALLI, R SURESHKUMAR	*
	Comparative Evaluation of Reparative Dentin Formation by Using Different Pulp Capping Agents: An In Vivo Study SNEHA MALI, SALEEM MAKANDAR, T.M. MANGALA, ABHIJEET PHASE	*
	Application of RP-HPLC method for stability study and quantifying decitabine in bulk drug and in pharmaceutical dosage form SHIV GUPTA, NEETU SACHAN, PHOOL CHANDRA, ARUN KUMAR SHARMA	*
	Atherosclerosis and lifestyle modifications: An Overview MAHIMA BHARATHI, SANDRA RAJENDRAN, NEETHU C.M, NAMITHA MARIA JACOB	*
	New safety signal for psoriasis associated with Angiotensin receptor blockers: qualitative and quantitative analysis using Pharmacovigilance tools HARDIK BHATT, TUSHAR DESAI	*
	Preparation and Evaluation of Valsartan Cubosomes P.VISHNU , N.SADHANA, K.NAVEENBABU, M.SUNITHA REDDY, K.MAHESWARI	*
	Evaluation of phytochemical and antibacterial activity of the crude extracts of Senna auriculata (L) THAMIL V, N. BALASUBRAMANIAN, V. SHANMUGAIAH, C. KARUNAKARAN	*
	Evaluation of streptokinase efficacy on the elimination of thrombosed tunneled-cuffed central venous catheter obstruction in hemodialysis patients HOSSEIN HEMMATI, MOHAMMAD TAGHI ASHOOBI, REIHANE EINOLLAHZADE, CYRUS EMIR ALAVI, MOHAYA FARZIN, ZAKIYEH JAFARYPARVAR, GHAZALEH HEMMATI	*
	Formulation and evaluation of mucoadhesive buccal patch containing captopril CHAUDHARI KANARAM, ABHISHEK SHARMA, SHWETA AGARWAL, RB SHARMA	*
	Investigation phytochemical screening, antibacterial activity, and cytotoxic ethanolic extract of Geodorum densiflorum (lam.) Schltr from papua ELSYE GUNAWAN, VERENA AGUSTINI, EVA SUSANTY SIMAREMARE	*
	Molecular Screening of Virulence Genes among Uropathogenic Enterococcus faecalis Isolated from patients in Al-Najaf City, Iraq ZAID ABED, NABIL SALIM SAAID TUWAIJ	*

SHASHANK CHATURVEDI, MOHAMMAD ALIM	
Novel technique used in the design of floating tablets of captopril and	
its evaluation MUNAGALA RAMYA, KOTHAPALLI BANNOTH CHANDRASEKHAR	*
Chloroquine and Hydroxychloroquine: the real saviours of Covid 2019? RAVICHANDRA RAVI, CHARISHMA CHOWDARY PONUGUBATI, ROOPESH BORUGADDA	*
Prescription writing skills among Dental Students in East-coast India. M. PRASUNNA, P. ARCHANA, G. BHAVANA, SURESH CHAND YADDANAPALLI, PARVEEN SULTANA SHAIK, SRINIVAS RAVOORI	*
An Efficient Classification of medical Images using Deep Learning	
Technique ADALINE SUIJ.R, SANTHI.S, UDAYAKUMAR.E, SASIKALA.R, BRIGHT ANAND.D	*
Predictors of Quality of life (QoL) among Qadisiah medical student, Iraq. HADI SUHAIL, ALI ABDULHUSSEIN MOUSA, SAAD MASHKOOR WALEED, YASMEEN ALI HUSSIEN	*
Reflections on COVID-19 in India: A Survey M. BALASUBRAMANIAN, S.BALAKRISHNAN	•
Evaluation of Hepatoprotective Potential of Solanum melongena L. Fruit Peel Extract against Carbon Tetrachloride Induced Liver Damage in Wistar Rats JAIDEEP SARKAR, NITIN KUMAR, PANKAJ GUPTA	*
Metronidazole: Crystal Growth and its Structural Refinement RANJANA SHARMA, DIXIT PRASHER, R. K. TIWARI	
"Stability Indicating RP-HPLC Method Development and Validation for the Estimation of Remogliflozin Etabonate in Bulk and Pharmaceutical Dosage Form"	*
TUSHAR BHATKAR, AMOL V. BADKHAL, NITIN S. BHAJIPALE	
Pharmacokinetic & Therapeutic Efficacy of Hydrocholorthiazide with Losartan in Treatment of Hypertension by LC-MS/MS GOUTAM MUKHOPADHYAY, SHYMODIP KUNDU, TRIPTI PAL, DEBASMITA MANNA, SAIKAT BHUNIA, PIYAL MAJUMDER, PAYAL JANA, ADITYA SARKAR	*
Hydrogel Systems: Their Classification, Preparation and Biomedical	
Applications SUMALATDA BALAMURUGAN, MANISHA MURALI, ARAVINDHANATHAN VENKATESAN, NAGASAMY VENKATESH D	*
Medicinal Plants Used in Herbal Cosmetics with Special Reference to Anti-Dandruff SHIV BAHADUR, RANJIT K. HARWANSH, PRASHANT KUMAR	*
Perception on Novel Phytodrug Delivery System: NPDDS in Herbal	
Medicine ARCHANA. I, SELVAKUMARI. E, GOPAL. V	*
Association of Childhood Obesity with Obese Parents and Other Familial Factors: A Systematic Review ANKITA AWASTHI, BHASKAR GUPTA, PAPIYA BIGONIYA	*
Biological Activities of Isatin Thiosemicarbazone Derivatives and their Metal Complexes: A Review of Past Three Decades (1991-2020)	*

A pilot study on jimutaka vamana yoga in the management of eka kushta w.s.r to psoriasis. MD HOSSAIN, MAHESH MP, CHIMANDA L KAMAR, SANGEETA T, RAHUL BANIK	*
Optimization of etodolac loaded emulsomes by box-behnken design of experiment VIVEK GILL, ARUN NANDA	*
Exploring impacts of breastfeeding during pregnancy to the mother in Indonesian society SHINTA RAHMAWATI, MUFDLILAH	*
Investigating of the Factors affecting the occurrence of Medical Errors: A Survey of the Process-Oriented Approach MORTEZA GHASEMI, MAJID TAHERI	*
Design, Development and Evaluation of Atazanavir Sulphate Agglomerates by Crystallo Co-Agglomeration Technique VEDANSHU MALVIYA,	*
Formulation and evaluation of diacerein microemulgel topical drug delivery. GANESH PAWBAKE, SATISH V. SHIROLKAR	*
DNA Sequencing of blaSHV Genes among Uropathogenic Klebsiella	*
Nutritional support with products of fruit origin in prevention of micronutrients deficiency in the "mother-child" system T.A. BOBOMURATOV, S.K. RASULOV, Z.A. DZHURAYEVA, A.A.SAMADOV, O.A.KULIYEV	*
Scabies complete clearance as a treatment efficacy: in Permethrin alone and in combined with oral Ivermectin: South Iraq-2019 DR. ABDULHUSSEIN	*
Influence of Wet Digestion Methods on Total Iron Content In Single And Combined Juices of Solanum Anguivi L. and Emblica Officinalis KARTHIKA PERIYASAMY, POONGODI VIJAYAKUMAR T	*
Anti-biofilm activity of Azadirachta indica and Ocimum sanctum Aqueous Extract Combination against MRSA SANCHIT SOOD, JOSEPH DAVIS	*
Analysis of Some Aspects of The Morbidity of Health Workers with Temporary Disability RAUSHAN ATANIYAZOVA, NURKHAN MUKHAMEDOVA, LOLA ISAKOVA, SAJIDA SHARIPOVA, HOSIYAT SADULLAYEVA	*
Computed Tomography in Early Staging for Lung Cancer JASUR HAQBERDIEV, GULBAHOR HODJAMOVA, MUNOJAT ISMAILOVA	*
Features of affective disorders and compliance of patients with chronic renal failure receiving replacement therapy by hemodialysis VASILA ABDULLAEVA, BOTIR T. DAMINOV, ABDULAZIZ A. NASIROV, JANNA T. RUSTAMOVA, YULIYA A.YEN	*
Optimizing the treatment of biliary disease in children with viral hepatitis FATIMA MAMATMUSAEVA, LAZIZ TUYCHIEV, ZUKHRA NURUZOVA, NODIRA YODGOROVA, ZUKHRA ORINBAEVA	*

Analysis of factors contributing to neurotic disorders associated with stress in female football players GAVKHAR TESHABAEVA, ISKANDAR MAVLYANOV	*
The new coronavirus - C?VID-19 in Uzbekistan GULBAHOR MATNAZAROVA, OMONTURDI MIRTAZAEV, ELENA BRYANTSEVA, MUATTAR ABDUKAKHAROVA, NIGORA NEMATOVA, NILUFAR KHAMZAEVA	*
Effectiveness of the method of nirvana innovative system in the neurorehabilitation of children with hiv- encephalopathy SAIDA SAIDKHODJAEVA, YAKUTKHON MADJIDOVA, ASAL ABDUVAKHITOVA	*
Self-education of medical students as a Factor of their professional development DILNOZA USTA-AZIZOVA, KHULKAR LUTFULLAEVA, RANO IBRAGIMOVA	*
Radiological value of computed tomography in degenerative disease of temporomandibular joint GUZAL KHAYDAROVA, MARAT KHODJIBEKOV, RAKHIM YAKUBOV	*
Monooxygenase liver system in functional changes of the thyroid gland experiment NASIRDJAN YULDASHEV, MOHIDIL RASULOVA, MAHAMADJAN NISHANTAEV, MUHAMMADAMIN SHERTAEV, GULCHEHRA SULEYMANO	
The level of biogenic amines and activity of cholinesterase's in patients with uterine myoma NILUFAR AKHMEDOVA, SHOISTA GOZIYEVA, MAKHLIYO MAMADIYEVA, SHOHIDA SATIMOVA, GULRUH QUZIYEVA	*
Endometriosis experience of non-hormonal drug therapy ASRANKULOVA DILORAMKHON, ABDHULLAEV RASOOL, ABDHULLAEVA MALIKA, MAMADJANOVA SHAKHNOZ, ABDUKAKHOROVA SEVARAKHON	፟
Fertility recovery from polycystic ovarian syndrome BAHODIR IBRAGIMOV, DILDORA KHUDOYAROVA, NADIYA IBRAGIMOVA, ZARINA KOBILOVA	*
Developmental history of pediatrics in Turkestan TAGAEV MAMARAZAK, AKHMEDOVA MUBORAK, KARIMOVA MIYASSAR	*
Specific course of the clinical and neurovisual features of the cerebral stroke caused by reversible cerebral vasoconstriction syndrome ELYOR TASHKENOV, GULNORA RAKHIMB?EVA, DILFUSA ABDUK? DIROVA	*
Differential diagnostic criteria for dilatational cardiomyopathy and nonreumatic myocarditis in children DILOROM AKHMEDOVA, DILFUZA RUZMATOVA, NIGORA ALIEVA, SAYYORA AKHMEDOVA	*
The share of hereditary nephritis in the nozological structure of nephrological diseases among children in andijan region MARIFAT GANIEVA, MUQADDAS BOLTABOEVA, OKSANA YEFIMENKO, UMIDA GANIEVA, LOLA HAYDAROVA, ZUVAYDA MIRZAEVA	*
Clinical evaluation of the course of dilated cardiomyopathy in children depending on the debut of the diseases YEFIMENKO OKSANA, HOLMATOV DAVRON, GANIEVA MARIFAT, GANIEV ABDURASHID, KHANKELDIEVA HURMATKHON, GANIEVA UMIDA	/

ARSHEED IQBAL, HAIDER ALI QURAISHI, SHABIR AHMAD BHAT, AFROZA JAN, ADIL RASHID	
Tumor Necrosis Factor – a gene polymorphism in Gasoline prolonged exposure workers HADEEL AL-RRUBAEL RANA S. JAWAD	*
Role of Charcoal as a limitation of a carbamazepine poisoning ENAMM ABDULLAH	*
Analysis of The Prevalence of Bronchial Asthma In Children In Outpatient Clinics. ZAKIROVA IRKINOVNA, JUMANOV DAVLAT OZODBEKOVICH, ABDULLAYEV ULUGBEK PULATOVICH, BOBAMURATOVA DILNOZA TURDIKULOVNA, MIRRAKHIMOVA MAKTUBA XABIBULLAYEVNA	*
Synthesis, characterization and Study Bioactivity of Silver Nanocomposites MAIDA SALEEM, BASMA J. AHMED	*
Synthesis, polymerization and characterization of new poly (3,5- substituted-1,2,4-triazole from different nitriles and study their effect on anticancer and antioxidant. BAHAA HAMZAH	
Association between Serum Leptin Level and Insulin Resistance in Acromegalic Iraqi Patients with Type 2 Diabetes Mellitus HIND AHMED, WALAA AHMED AL-JEDDA, NOOR THAIR TAHIR	*
Follow-up of patients infected with Cystic Echinococcosis by measuring some immunological indicators before and after the removal of hydatid cysts ABTISAM QASIM, JAMEEL JERRI YOUSIF	*
Optical properties of different organic compounds: experimental and theoretical studies RAGHAD HATAM, ZAID M. ABBAS, MUSTAFA M. KADHIM, RAWAA A. KADHIM, SAIF I. MUSLIM	*
The Problem of Increasing Number of Myocardial Infarction: Deaths in Densely Populated Cities USTINYA S. VASILEVA, ADELINA R. GALYAVEEVA, ALINA I. KHAERZAMANOVA, ALEXANDER N. RASIN, PAVELN.KISLYY, LILIJA M. ALLANINA, ELIZAVETA S. KONEVA	*
Effect of Purple Sweet Potato Extract Administration to Cigarette Smoke Exposure towards The Number of Androgen Receptors: Randomized controlled trial I, I GUSTI AYU RATIH AGUSTINI*, I NYOMAN MANGKU KARMAYA, I MADE JAWI, BAGUS KOMANG SATRIASA	*
Cholinesterases inhibitors for treating Alzheimer's disease RANIA BAKR	*
Physiological effects of Prozac on cellular and Humoral components of blood of laboratory mice SHAYMA HANOON, AIAD GABER AREAN, WISSAM SAJID HASHIM	*
The Measurement and Histological Study of The Venom Gland and Acul Sting In Iraqi Scorpio maurus Linnaeus, 1758 ZEINA AL-AZAWII	us
Synthesis and Characterization of some New Heterocyclic Compound containing Triazolidin derivatives and study their biological activity	

	nily AMAT SAIDOV	
gla SH	e reaction of newborn rats' tissues to the functional state of thyroid nd of the female lactating rat AIRA KARIMOVA, NOSIR YULDASHEV, ZUHRA ZIYAMUTDINOVA, RSHIDA AKBARKHODJAEVA, NASIRA ALIMHODJAEVA	
ZĖ	ganization of medical care for patients with eye injuries BINISO NIYAZOVA, SURAT GULYAMOV, UMIDA GANIEVA, LYUBOV EGAY, AYUBHON KAYUMOV	
ph	rspectives of immortality (helichrysum) in modern medicine and armacy S. KARIEVA, R.K. SADIKOVA, K.N. NURIDULLAEVA	
so SA	cleophilic substitution reaction of dichloroacetyl hydroquinone with dium salts of oxyacids BOHAT SADIKOVA, ANVAR ABDUSHUKUROV, AZIMJON CHORIYEV, LDASH TAKHIROV	1
dis SA	namics of clinical and neurological indicators in children with speed orders on the background of transcranial micropolarization YDOLIM USMANOV, YAKUTKHON MADJIDOVA, DILDORAKHON HMEDOVA, IRODA NASIROVA, MUKHAMMADJON BOSIMOV	ch
	emotherapy tolerance in children with tuberculosis TIMA TASHPULATOVA, MAHLIYO ABDUSALOMOVA	2
	ationship between photos and ICT ILNORA TASHMUKHAMEDOVA	¥.
div	orovement of the regulation mechanisms of the land use ersification TIEV ABDURASHID, MAHSUDOV MUHAMMADBEK	
dy: UN	sults of molecular genetic studies of progressing muscular strophies of dushen/Becker in Uzbekistan IIDA OMONOVA, YAKUTKHON MADJIDOVA, UMIDA BABADJANOVA, IDIRA KHAMIDOVA, KAMILJON BOBONIYAZOV	
in l	tended Spectrum Beta Lactamase E. Coli isolated from UTI Patients Najaf Province, Iraq UALFAKAR HASAN	
NA	velopment and Evaluation of IER based Formulation of Ondansetrol DIR KHAN, HARJEET SINGH, VIDHAN CHAND BALA, VIKAS ANAND HARAN	n H
fini K.A	e relationship of the adhesion of the oral cavity microorganisms wit shing method of dental material restoration N. SARYCHEVA, S.V. KAMENEVA, N.V. KUSHCHENKO, L.A. KRAEVA, IKOVA	
Sy: BE	pects of Medical and Ecological Services in Natural Water Bodies stem LLA KHASHIR, SAIDA OLEGOVNA APSALYAMOVA, OLEGE CHIRIEVICH KHUAZH	
	rona virus - herbal approach for boosting immunity and influencing	

WISAM KURDI, SHIREEN RIDHA RASOOL	
Cinnamon Toothpaste Influence Enamel Demineralization SHAHAD AL-JANABI, RAHMA H. AL-HUSSAINY, BAYDAA ALI OTHMAN AL- RAWI	*
Synthesis of a novel Three-Dimensional nano co-polymer and studying the Ability of Drug Delivery System MAYYADAH ABD, MOHAMMAD N. AL-BAIATI	*
Synthesis a novel nano co-polymer and using as carrier drug system AMEL HASAN, MOHAMMAD N. AL-BAIATI, MOHANAD M. KAREEM	*
Synthesis, identification and structural of some transition metal complex with New heterocyclic azo-schiff base ligand derived from 4-amino antipyrine	
LAYLA MOHAMMED, ABID ALLAH MOHAMMED ALI, RAHEEM TAHIR MEHD	"
Serological detection and hematological changes associated with Toxoplasmosis in thalassemia patients in Al-Samawah province NUHA MOUSA	*
Physicochemical Stability of Mixed Dexamethasone and Diclofenac Inject ZAINAB ABDUL, ZAID M ABDUL KHALIK, MOHAMMED KHUDHAIR HASAN, RAND FARHAD	ion
Testing the activity of Alkaloids extracted from Clorella volgaris on the viability of Trichomonas vaginalis In vitro AMAL KHALAF	
Oxidative stress status in sera and seminal plasma and their correlation with lead (Pb) and cadmium (Cd) in Iraqi infertile male. SUHA HASAN, HATHAMA RAZOOKI HASAN	*
Preparation and evaluation of porosity osmotic pump tablets for sustain release of Glimepiride NUHA ABDULKHALEQ, AMAL A. ELKORDY, WEDAD K. ALI	*
Effect of Some Fillers on The Polyethylene Properties TALEB HASSEN	
Antimicrobial studying of (Imidazole) derivative from pyrimidine ASEEL KAREEM, HASAN T.QHANIM	¥
Synthesis, Characterization, Theoretical Study and Biological Activity of Schiff base Metal Complexes Derived from Cefotaxime with 5, 5-diethyl-6-iminodihydropyrim idine-2, 4(1H, 3H)-Dione SAHAR HASSAN, ZAHRAA N. ABD, NAFEESA J. KADHIM, NIDHAL M. HASSAN	*
Etodolac Topical Spray Films, Development, Characterization and In- Vitro Evaluation ZAINAB SADEQ, ZAHRAA SALIM, ESRAA GHAZY	*
A Qualitative Exploration of Learning to Break Bad News among Medical Students in University of Cyberjaya RAFIDAH BAHARI, NORHAFIZAH AB MANAN, MARIA ZALINA ABD RAHIM, KAMALIAH MOHAMAD NOH, KRISHNA GOPAL RAMPAL, ABD RAHIM MOHAMAD	*
The Islamic Psycho-spiritual Therapy for Posttraumatic Stress Disorder (IPSP): A Study of Feasibility and Effects RAFIDAH BAHARI	*

The Impact of Helicopter Parenting on Mental Health through Self- efficacy among University Students CHEAH LIN, MARIA ZALINA A. RAHIM	*
Extraction and Optimization of Phenolic Compounds from Sesbania Grandiflora Flower Using Response Surface Methodology K.K. MOHANA, M.S. SHIVASAMY, J. JONY BLESSING MANOJ, S. SHANGAVI	*
Evaluation of Primary Health Care (PHC) - Universal Health Coverage (UHC) Alignment Using Modified Self-Assessment Tool in Malaysia KAMALIAH NOH, SITI HANIZA MAHMUD, MOHD SAFIEE ISMAIL, IZZATUR RAHMI MOHD UJANG, RUSDI ABD RAHMAN, KOH KAR CHAI, RIMA MARHAYU ABD RASHID, NUR EZDIANI MOHAMED, AKMAL AIDA OTHMAN, ZURRIYATI YA'KUB, ROZITA HALINA HUSSEIN	⊁ ∘
Optimization of Bioactive extraction from Solanum Nigrum Leaves by Response Surface Methodology and its Encapsulation by Spray Drying for Functional Foods S. KAVIYA, S. KANDASAMY, K. KEERTHANA, R. MENAHA	*
Construct Validity and Reliability of the Adherence to Malaysian Cupping Practice Guideline Questionnaire for Cupping Practitioners M. AIN, AR. ZAIRINA	*
Sodium Content in Processed Food in Major Retail Outlets in Malaysia K.J. MARYAM, N. NANI, A.R. RAHMAN	*
Knowledge and Awareness Related to Salt in Food among Malaysian Young Adults K.J. MARYAM, N. NANI, A.R. RAHMAN	₩
Correlation Study between Estimated 24-Hr Urinary Sodium Using Tanaka and Kawasaki Formula and Measured 24-Hr Urinary Sodium K.J. MARYAM, N. NANI, A.R. RAHMAN	
Prevalence and Factors Associated with Abdominal and overall Obesity in Sepang, Malaysia NUR MAHAT, NORHAFIZAH AB MANAN, SABARIAH ABD HAMID, AHMAD FAIRUZ MOHAMMED, KAMALIAH MOHD NOR, ABD RAHIM MOHAMAD, KRISHNA GOPAL RAMPAL	¥⊚
Factors Affecting Mother's Adherence towards Cerebral Palsy Home Exercise Program among Children at Hebron and Bethlehem, Palestine MOHAMMED TAHAYNEH, SYEDA HUMAYRA, ABDOUL AZIZ FALL, HANNAH ROSLAND, AKRAM AMRO, ABDELKODOSE MOHAMMED, ABD. LATIFF MOHAMED	* •
Mental Health Problems among the Local Community of Megah Villa Apartments in Sepang, Malaysia SAHIRA SAHIMI, SITI SARAH ROSLI, ABD RAHIM MOHAMAD	*
Feedback on Multimodal Gross Anatomy Practical Sessions: A Pilot	*
Study RESHMA ANSARI, SARA IDRIS, ATIKAH ABDUL LATIFF	
RESHMA ANSARI, SARA IDRIS, ATIKAH ABDUL LATIFF A Comparative Study of different Image Preprocessing Methods used	¥.

MANSOUR ABDULNABI, H. MEHDI, MAZAHAR FAROOQUI, VIDYA PRADHAN		
Evaluation and Reporting of Medication Errors (MEs) In A South Indian Teaching Hospital POOJA SAGAR, THARA MARIYAM SUNNY, PRAMOD SAM, ALLURI SIVA CHAITHANYA VARMA, JUNY SEBASTIAN, JUSTIN KURIAN, ADEPU RAMESH	*	
Hypoxic ischemic encephalopathy and sepsis: A case study DR. S., SHIV DINESH DYARAPOGU, MUNEB AHMED SYED, MOHAMMED SAFI UR RAHMAN, AMAL TEJ MATTHEW, PURUCHURU AJAY	*	
Hydrothermal Deposition Of TiCL4 Solution To Produce TiO2 Particles On The Surface Of Meranti Wood (Shorea Sp) KASMAN EDIPUTRA, SYUKRI, EMRIADI, HERMANSYAH AZIZ	¥	
Formulation and Evaluation of Ibuprofen Lozenges SIHAM ABDOUN, MALAK G. ALMUTAIRI	*	
Perceptions and knowledge of parents of Saudi children on the efficacy of Nigella Sativa extracts in prevention of caries and gingival inflammation. HANADI ALWAFI, ABDULLAH ALFAYEZ, JAYAPRIYAA SHANMUGHAM, ATHANASIOS ZAVR	*	
Study the perceptions, effectiveness and adherence Pattern of anti- diabetic drugs prescribed for type 2 DM patients in some Iraqi hospitals specialized diabetic centers and private pharmacies. 20160737/5609 ZAHRAA ALB	^{5,} *	
Formulation and evaluation lipid polymer hybrid nanocarriers using a new innovative microwaves based method , , HAYDER KADHIM DRAIS, AHMED ABBAS HUSSEIN	*	
Evaluation of Serum Lipid Profile after Treatment with Various Chemotherapeutic Scheduals in Iraqi Breast Cancer Patients ZAINAB ANBER	¥	
Investigation of Antibacterial Effect and Expression of Alkaline Proteasingene in Pseudomonas Aeruginosa (PAO1) Using Copper Oxide, Copper Complex and Satureja Khuzistanica: RT-PCR Method RAZIYEH MOHSENI, MEHRI HOSSEINI, MEHRORANG GHAEDI, ASGHAF SHARIFI, HAMID REZA MOHAMMADI, FOROUGH MORIDIKIA, HASSAN ABIDI, DAVOUD ESMAEILI, SEYED REZA KHOSRAVANI, SEYED ABDOLMAJID KHOSRAVANI	r	
Distinctive feature analysis to establish biochemical & spatial configuration of Bacopa monnieri NIBEDITA DEY, KOYAL R, MOHANAMBAL M	*	
Cusp of Carabelli in maxillary molars – A cross-sectional study NIVEDHA M, K. R. DON	*	
Association Of Age And Gender In Patients With Class V Caries Indicated For Root Canal Treatment In The Age Group 60-80 Years ASHWIN KUMAR.S.P, SURENDAR SUGUMARAN, SREEDEVI DHARMAN	*	
Prevalence of Average, Horizontal and Vertical Growth Pattern in Patients with Class I Malocclusion -A Retrospective Study PURVA VERMA, ARVIND S, NAVEEN M. KUMAR	*	

FLORA LOOI, FARAH FAIDAH BINTI FADZIL, SAZLIN AFFINA BINTI SAHIMI, MAD AL-FAQIL BIN WASIMAN, FEISAL HILMAN, RAFIDAH BAHARI	
A Review on Bird Classification on Different Dataset P. RANJITHA, M.U. ANUSHA, C. PRAGNA SHEKHAR, PRIYANKA P SHETTY, R. PUNEETHA	*
Wild Animals Intrusion Detection using Deep Learning Techniques R.S. SABEENIAN, N. DEIVANAI, B. MYTHILI	*
Edible Landscape in Future Kerala C.S. ANANDALEKSHMY, ATHUL V KRISHNA, MOBIN JOHN, DAYANA DAS	s *
A Study of COVID-19 Symptoms Using Fuzzy Cognitive Map A. KANCHANA, VINITHA NAVIS VARUVEL	*
Automatic Detection of Malarial Parasites from Blood Cells Using Soft Computing Techniques K. KARUNHARAN, X. ANITHA MARY	*
Synergistic and Localized E-Commerce Application K. NAVEEN, K. SUJITH CHANDRA, S. PRAYLA SHYRY	*
Brain Tumor Segmentation and identification based on Image Processis FCM Clustering Algorithm A. KHAN, P. PRAVINA PRIYA, R. PRIYATHARSINI, A. RAESHMITHAA, R. RAMYA	ng
Zigbee based Condition Monitoring in AC Motors Using ATmega16 M. AMUTHA, A.P. JAYA KRISHNA, S. RAMKUMAR, B. OVIYAA	*
Level of vaspin and some variables in serum of Diabetes mellitus patients with different age in Najaf city AHMED ABBAS, AHMED ZUHAIR JASIM, EBTIHAL CHIAD ABASS	*
Effectiveness of biologically active substances from Hypericum Perforatum L. in the complex treatment of purulent wounds YURY VATNIKOV, PAVEL RUDENKO, MARINA SHOPINSKAYA, ANNA TOKAR, VERA ZHILKINA, DMITRY BOKOV, NATALIA BOBKOVA, NADEZHDA SACHIVKINA, EKATERINA LENCHENKO, ARFENIA KARAMYAN, EVGENY KULIKOV, SERGEY SHABUNIN	*
Flax seeds – medicinal and edible herbal materials BOKOV D.O., SULEYMANOVA M.S. KOLESNIKOVA V.V., CHEVIDAEV V.V SAMYLINA I.A, KRASNYUK I.I. (JUNIOR), BESSONOV V.V., SOKHIN D.M., RENDYUK T.D, JANULIS V., KURBANOVA M.N, AFANASYEV N.V	
Implications of Click Chemistry on Human Health SMRITI SHARMA	*
In vitro study of antibacterial and antioxidant properties of urine of indigenous Badri cow VIPIN NAUTIYAL, R.C. DUBEY	*
Current regulatory requirements for cosmetics in USA and India MRS. SAVITHA, DR. M. P. VENKATESH, DR. BALAMURALIDHARA V.	
'Iranian perioperative Nurses' Perception of Moral Courage and Its Relationship with the Professional Values MARYAM CHEHREHGOSHA, ZAHRA ROYANI, SOHEYLA KALANTARI, NEDA ASADI, FATEMEH HOSEINI, NAVISA SEYEDGHASEMI	*
Evaluation of antiamoebic activity of Ziziphus mauritiana leaf extracts in rats experimentally infected with Entamoeba histolytica	n 🚜

Analysis of young adults with Midline diastema opting Orthodontic correction JANHVI MANOHAR, S.P. SARAVANA DINESH	*
Aloe vera as an herbal remedy in dentistry KAVIYA.L., DR. JAYALAKSHMI SOMASUNDARAM	*
Prevalence of gingival bleeding during cord packing B.AISHWARYA REDDY, DHANRAJ GANAPATHY. M, NIVETHIGAA. B	*
Assessment of prescribing pattern, adverse drug reactions and psychological distress in cancer patients at Erode Cancer Centre BHAVATHARINI SUKUMARAN, JINCY JAMES, KRISHNAVENI KANDAS SAMBATHKUMAR RAMANATHAN, SARAVANAN GOVINDARAJ, VELAN KANDAPPAN	
Matricaria chamomilla extract inhibits the metastatic potential of colorectal cancer cell line via reduction of matrix metalloproteinase enzymes activity HASSAN ABIDI, NAZANIN DANAEI, REZA MAHMOUDI, AREZOO SABE MANSORE ESMAEILI, MOHSEN NIKSERESHT	₩
Assessing the Effect of Process and Formulation Variables on Quali of Solid-Lipid Nanoparticles by Quality by Design Approach SANDHYA JAISWAL, G.D. GUPTA	ty *
Prevalence of Co-Morbidities Associated with Hypothyroidism Amor Infertile Women VIMALA PRASANNA, SHARUMATHI S. M, CINDY JOSE, SHANMUGA SUNDARAM. R	ıg *
Improving Shelf Life of Pharmaceutical products with Six Sigma: A C study ABDALLAH ABDALLAH	ase 🐥
Association between Severity of Decompensated Cirrhosis Measure with Model of End-Stage Liver Disease Score and Plasma Fibrinoger Level LUTHFIAJANNAH, POERNOMO BOEDI SETIAWAN, MADE PUTRA SEDANA	
Mechanism of Systemic Inflammatory Regulation in Sepsis Rat Mod Through the Role of HMGB1, IL-1?, IL-10 and Procalcitonin in Statin Administration MUSOFA RUSLI, USMAN HADI, JUSAK NUGRAHA	els *
Procalcitonin, IL-16, HSP10 and Resolvin D2 Mechanism as Sepsis Biomarkers in Sepsis Model MUHAMMAD AFRIJANTO, USMAN HADI, YOES PRIJATNA DACHLAN	*
In vitro cytotoxicity of Dragon Fruit Extract (Hylocereus polyrhizus) (Fibroblast Cell Culture WISNU JULIASTUTI, HENDRIK SETIA BUDI, DINDA AKHLAKUL KARIM	*
Maternal Cardiovascular Risk in Five Years after Labor with Early- at Late-Onset of Severe Preeclampsia ADITIAWARMAN, ERNAWATI, HERMANTO TRI JOEWONO, MUHAMMILHAM ALDIKA AKBAR, NOOR ASSYIFA ZULHIJAYAN	w.
The Effect of L-Arginine on Placental Growth Factor Serum Levels in Mouse Models with Preeclampsia ADITIAWARMAN, MANGGALA PASCA WARDHANA, DIANA APRILYAN NUR, HERMANTO TRI JOEWONO	V.

The Effect of L-Arginine on Diameter of Spiral Artery and Fetal Weight between Normal Pregnant Mice and Preeclampsia Mouse Models ADITIAWARMAN, MANGGALA PASCA WARDHANA, LALITA EKA PERVITA SARI, HERMANTO TRI JOEWONO Mozart's Compositions during Pregnancy Increase Newborns' Umbilical Serum Brain-Derived Neurotrophic Factors HERMANTO TRI NIKEN WENING SURYANTI MARGARITHA MUHAMMAD DIKMAN ANGSAR, AGUS SULISTYONO, ADITIAWARMAN HbA1c as a Predictor of Fetal Outcomes in Pregestational Diabetes Mellitus HERMANTO JOEWONO, RATIH, AGUS SULISTYONO, ADITIAWARMAN Procalcitonin, IL-1ß, HSP10 and Resolvin D2 Mechanism as Sepsis Biomarkers in Sepsis Model
MUHAMMAD AFRIJANTO, USMAN HADI, YOES PRIJATNA DACHLAN Mechanism of Systemic Inflammatory Regulation in Sepsis Rat Models Through the Role of HMGB1, IL-1?, IL-10 and Procalcitonin in Statin Administration
MUSOFA RUSLI, USMAN HADI, JUSAK NUGRAHA Association of Liver Fibrosis based on Transient Elastography and Quantitative HBsAg Levels in HBeAg-Positive Chronic Hepatitis B Patients
TITONG SUGIHARTONO, DEBRINA KUSUMA DEVI, TITONG
SUGIHARTONO, UMMI MAIMUNAH, ISWAN ABBAS NUSI, HERRRY
PURBAYU, ULFA KHOLILI, BUDI WIDODO, MUHAMMAD
MIFTAHUSSURUR, HUSIN THAMRIN, AMIE VIDYANI, POERNOMO BOEDI Effect of Home Bleaching Agents on The Surface Hardness Of Flowable Bulk Fill Resin Composite

DWITA ANGESTI, PRIYAWAN RACHMADI, ANITA YULIATI Diagnostic for COVID-19: Application for Developing Countries ARYATI ARYATI, ERSA BAYUNG MAULIDAN, MUHAMMAD MIFTAHUSSURUR Comparison of Diagnostic Value of Rapid Diagnostic Test Standard Q towards Microscopic and Nested Polymerase Chain Reaction in Suspected Malaria Patients AMARENSI BETAUBUN, CHRISTOPHORUS OETAMA ADIATMAJA TRIEVA V BUTARBUTAR, ARYATI, PUSPA WARDHANI Association Between Neutrophil-Lymphocyte Ratio and Therapy Response in Diffuse Large B-Cell Lymphoma Patients Undergoing R-CHOP Chemotherapy SHEILA NALIA, S.UGROSENO YUDHO BINTORO, MADE PUTRA SEDANA, AMI ASHARIATI The Level of Nutritional Adequacy, Physical Activities, and Body KARTIKA DEWI, MERRYANA ANDRIANI Gingivectomy Management For Fixed Orthodontic Treatment MASRIANA YASIN, IRMA JOSEFINA SAVITRI Changes in C- Reactive Protein/Albumin Ratio and Mortality within 30 Days in HIV/AIDS Patients ETTY PRATIWI, USMAN HADI, MUSOFA RUSLI ×

MADE DANASWARI, R.MOHAMMAD YOGIARTONO, PRIYAWAN RACHMADI	
The Effect of Chitosan from Squid Pens Toward Streptococcus Mutans SHERMAN SALIM, RATRI MAYA SITALAKSMI, FAILA SHOFA A, NIKE HENDRIJANTINI	*
Panoramic Radiography Observation Towards Mental Foramen Position NAZTASYA PUTRI, DENY SAPUTRA, YUNITA SAVITRI	*
Effect of Methanol Watery Extract of Cuscuta Chinensis in Rheumatoid Arthritis Induced Rats. AHMED SAADOON, DR.MUSTAFA GHAZI ALABBASSI, DR.NADIA HAMEED MOHAMMED	*
Effect of SIRT1 Activators on Human Follicular Thyroid Cancer LAMEES TALIB, MUSTAFA GHAZI AL-ABBASSI, BASMA TALIB AL-SUDANI	*
PTEN Polymorphism in Employees Exposed to Chlorine Doses atWater Purification Plants REEM K.IBRAHIM, AHMED SAMI FARHAN, MAHER R. ZEADAN	
Health Benefits of Green Tea and Green Tea Catechins with an Overview on their Anti-Cancer Activity AMEERA KHALEEL, DR. RAMIZU BIN SHAARI, DR. MOHAMAD ARIF AWANG NAWI, DR. ALI SULTAN ALRIFAI	*
Reasons for population dissatisfaction with primary health care ARTUR ALMUKHAMETOV, ANAS ANVAROVICH GILMANOV, ILDAR RUSHANOVICH ISKANDAROV, ARTUR MANSUROVICH ALMUKHAMETOV	
eHealth and Rare Diseases treatment in the frameworks of Cross-Border Healthcare: EU and EAEU. LENARA R.KLIMOVSKAYA	*
Assessment of Serum Zinc and Vitamin C as Antioxidants in Patients with Vitiligo in Babylon Province HADEER AL-HATTAB, BAN MAHMOOD SHAKER AL-JODA, MOHAMMED KADHUM AL-HATTAB	*
Correlation of VitaminD level with AMH and HMGB1 in pre and post- menopausal women in Babylon province SHAIMA R.IBRAHEEM, THANAA ABDULMAHDI MOKIF, RAHEEM TUAMA OBAYES AL- MAMMORI, HUSSEIN O.M. AL-DAHMOSHI, NOOR S.K. AL- KHAFAJI	*
The Association Between Genotypes And Clinical Symptoms Of Giardia Lamblia In Patients With Symptomatic Giardiasis SUNDUS AL-HUCHAIMI, MOHAMMED KAMIL AL-HASSANI, ABDULKAREEM KHATTAR SHAALAN ALHATEMI, MAJIDA MALIK METEAB ALSHAMMARI, THIKRA A.MAHMOOD	*
Inhibition of Staphylococcus aureus Growth Isolated from Teeth Decay Using Pomegranate Fat Extract Fortified by Silver Nanoparticles (AgNp) MOHAMMED FADHIL HADDAD, SAFAA.M. SULTAN	*
The Relations of Knowledge, Attitudes, and Precautions with Asthma Control Levels in Patients With Asthma TINTIN SUKARTINI, ACHMAD RASYID RIDHO, HERDINA MARIYANTI	♣
Relationship of The Family Health Task Implementation with Motivation and Adherence of Tuberculosis Treatment among Tuberculosis Patients	*

TINTIN SUKARTINI, ALFIATIS SU'UDIYAH, LAILY HIDAYATI

MADE DANASWARI, R.MOHAMMAD YOGIARTONO, PRIYAWAN

Association of Initial Vitamin D Level with CD4 Cell Count Changes in HIN Naïve Patients Receiving Antiretroviral Therapy ROSITA BASKORO, USMAN HADI, MUSOFA RUSLI	/-
Side Effects of Drugs in Patients with Nasopharyngeal Carcinoma Receiving Neoadjuvant Chemotherapy NADHILA PRATIWI, MUHTARUM YUSUF	*
Pediatric Logistic Organ Dysfunction-2, Pediatric Risk Of Mortality-IV And Pediatric Index Of Mortality-3 For Predicting Mortality In Pediatric Surgery Patients With Sepsis JEMMY SUTANTIO, FENDY MATULATAN, EDWIN DANARDONO, DOMINICUS HUSADA	*
The Effect Of 5% Povidone-Iodine Irrigation Compared To 0.9% NaCl In The Post Laparotomic Post Laparotomic Patient Network On The Number Of The Surgical Site Infections In Dr. Soetomo Hospital, Surabaya ALBERT LIMANAGO, VICKY SUMARKI BUDIPRAMANA, TOMY LESMANA, EDWIN DANARDONO	*
Release of Fluoride to the Addition of Nanoparticle Zinc Oxide with Glass Ionomer Cements LARASATI PUTRI, DEVI RIANTI, ENDANUS HARIJANTO	*
Association of 25-Hydroxyvitamin D Concentration and Frailty Degree in Elderly Community in Surabaya SARAH YUNARA, NOVIRA WIDAJANTI, JUSRI ICHWANI	*
Application of Purple Leaf Extract (Graptophyllum Pictum) In Wound Healing Process of Collagen Density MUHAMMAD BRAHMANTYO, INTAN NIRWANA, DAN DEVI RIANTI	*
Inhibition Potency of Allicin in the Tooth Paste Against Lactobaciilus Acidophilus: In Vitro Study NG HAN, DEVI RIANTI, R.HELAL SOEKARTONO	♣
Relationship between Mean Platelet Volume and Platelet Distribution Width with Type of Diabetic Retinopathy LIBRIANSYAH, SOEBAGIJO ADI SOELISTIJO, AGUNG PRANOTO, WIMBO SASONO, DEASY ARDIANY	*
The Impact Strenght Of Heat Cured Acrylic With Citosan Nano Gel Combination. AHMAD FAUZI, ENDANUS HARIJANTO, SOEBAGIO	♣
Serum Ferritin Levels and Lipid Profile in Patients with Transfusion- Dependent Beta and Beta/HbE Thalassemia TEGUH S. WIBOWO, AMI ASHARIATI, S.UGROSENO YUDHO BINTORO, SOEBAGIJO ADI SOESLISTIJO	*
Correlation Of Mother's Behavior In Autistic Children With DMF-T Value And Dental Care Need INDAH PERMATASARI, TANIA SASKIANTI, MEGA MOEHARYONO	*
Papillary Bleeding Index in Public Health Service on Gingival Inflammation RATNA ALFIANDINI, CHIQUITA PRAHASANTI, POERNOMO AGOES WIBISONO	ێ
Rubbing Cacao Bean Extract In Improving Microhardness Enamel On Dental Bleaching	*

The Effect of Health Education with "Numbered Head Together" and Demonstration Methods on Menstrual Hygiene Behavior in Adolescent Islamic Boarding School ESTI YUNITASARI, KIFAYATUS SA'ADAH, SYLVIA DWI WAHYUNI, HARMAYETTY HARMAYETTY	*
Exclusive Breastfeeding Based on The Health Promotion Model in Madura Island ESTI YUNITASARI, ROFITA WAHYU ANDRIANI, SYLVIA DWI WAHYUNI	*
The Effect of Family Psychoeducation Therapy on the Anxiety Level of Family of Patients with CRF undergoing Hemodialysis HANIK NIHAYATI, DIAH LESTARI, LAILY HIDAYATI	₩
The Analysis of Family Support Factors in Exclusive Breastfeeding Based on Precede Proceed Theory MATILDIS SERAN, YUNI SUFYANTI ARIEF, IQLIMA DWI KURNIA	*
Maternal Behavioral Factors of Mothers with Neonatal Death in the Perinatal Period STEFANIA RAMDA, YUNI SUFYANTI ARIEF, ILYA KRISNANA	*
Does The Behaviour of Using Electronic Cigarette Correkates with Respiratory Disease Symptoms? FIDA AUNIAISMA, NINUK DIAN KURNIAWATI, PRABA DIYAN RACHMAWATI	*
Combined Benson and Dhikr Relaxation Reduces Anxiety and Pulse Frequency of Inpatient Cardiacs in Hospitals ABU BAKAR, SUHARTATIK SUHARTATIK, LAILY HIDAYATI	*
Relationship between Disease Duration and Preventive Motivation with Quality of Life of Patients with Coronary Heart Disease at Productive Age in Cardiology NINUK KURNIAWATI, YULIA PUTRI ARIYANTI, LAILATUN NIKMAH, ERNA DWI WAHYUNI	*
Study of the main factors influencing consumers' choice of innovative food products ISABEKOVA O.A., BATURYAN M.A., SURAY N.M., PETROVA, L., PETROVA, L.I., PEREDNIKH L.V, GOLOSHCHAPOVA L.V	*
Economic and Mathematical Models of Financial Incentives for The Personnel at Medical Organization Departments E.V.KOSTYRIN,	*
Analyzing the deduction of Serum Levels with Coronary Heart Disease ALII MOHAMMED, REZANI MAJEEDI OMER, SAMIRI ANWARI JABBAR	*
Study of the effect of organochlorine pesticides on biochemical transformations in the process of obtaining grape materials PANASYUK A.L., KUZMINA E.I, KHARLAMOVA L.N, BABAEVA M.V., ROMANOVA I.P, SHICHIYAKH R.A.	*
Relationship of Strength of Emulsions with Content of Oil in Aqueous Solutions of Corn Flour and Dry Milk VASYUKOVA A.T, ALEKSEEV A.E, MOSHKIN A.V, BONDARENKO YU.V, UTYUZH A. S, KULIK A.A	*
Human Resource Work-Life Balance and Job Satisfaction in Pharmaceutical Counselling Services at Cendrawasih University, Papua - Indonesia FERDINAND RISAMASU, OSCAR OSWALD OKTOVIANUS WAMBRAUW	*

Psychosocial Wellbeing of Oral Diseases among Malaysia Public University Patients FONNY HUTAGALUNG, AHMAD KAMARUL, HUTKEMRI ZULNAIDI, CHEW FONG PENG, NOOR AISHAH ROSLI, JAMALIAH KASSIM	. *
Soy Isoflavone Supplementation Reduces RANKL/OPG Ratio on Postmenopausal Women with Osteopenia ELLY HERWANA, RIANTO SETIABUDY, SIDHARTAWAN SOEGONDO, ALI BAZIAD, ADI HIDAYAT	*
Pharmacokinetic and Toxicological Studies of Liposomal Amphotericin B Eye Drops on the Rabbit Eye HUSNUN AMALIA, ARI ESTUNINGTYAS, RAHMAWATI RIDWAN, RATNA SITOMPUL, ROBIATUL ADAWIYAH, HANS-JOACHIM FREISLEBEN	*
Food Calorie Measurement and Classification of Food Images S.MOHIDEEN PILLAI, DR.S. KOTHER MOHIDEEN	*
Antioxidant and Sunscreen Activities from Blackberry Extract in vitro using Spectrophotometry UV-Visible NENI GUNARTI, ANGGUN HARI KUSUMAWATI, MAYA ARFANIA, FARHAMZAH, IIN LIDIA PUTAMA MURSAL	*
Ultrasonographic Assessment of Duration of Pregnancy by Utilizing Fetus Kidney Length in Second and Third Trimester DR.ZENA.M.AL HINDAWI	*
Breastfeeding in Postpartum Women Infected with COVID-19 CIPTA PRAMANA, JATI SUWANTORO, NENI SUMARNI, MEI LINA FITRI KUMALASARI, H.SELASIH PUTRI ISNAWATI, AGUS SUPINGANTO, KHOLIS ERNAWATI, LENNY IRMAWATY SIRAIT, NURAINI STARYO, NURHIDAYAH, KISROH DWIYONO	*
Social Workers Practices in Handling Corona Virus Pandemic with An Multisystemic Approach MUHAMMAD EQUATORA, JAMALUDDIN HOS, SULSALMAN MOITA, ZULHAM IBRAHIM, LA ODE MONTO BAUTO, IMAN SANTOSO	٭
The Use of Pharmaceutical Preparation of Phytosome Lepidium Sativum Extract as Anti-diarrheal Induced by the Bacteria E. coli in Mice FARRAH R.JAAFAR, SHROOQ J.JASSIM, MOHANAD A.AL-BAYATI	*
Study the Causes of the Spread of a Disease Polycythemia Rubra Vera, (PRV) In the Youth Stage, It is Reflected in Heart Diseases, Blood Pressure and Increased Hemoglobin DR.SALAH KADER	℀
Papillary Endothelial Hyperplasia in Breast Lesions DR.REGINA BLOSSOM, DR.BHEEMA RAO, DR.K.REKHA	*
Incidence of Incontinence after Lateral Internal Sphincterotomy in Almuthanna Province ALI SADEQ, HUSSIEN ALI AL-HAMDANI, AYAD YAS KHUDHAIR	*
Pathological and Enzymatic Effect of Corynebacterium Pseudotuberculo in the Liver of Mice Infected by Same Pathogen K.J.AWNI , MUAYAD ABBAS HUSSEIN, T.G.Y.AL BADRRAWI, HUSSEIN H.NAHI	osis
Extraction and Purification of ß-Galactosidase from Lettuce (Lactuca sativa L.) SARI HUSSIEN, ABDULHAKEEM DAHHAM HUSSEIN, OTHMAN GHAZI NAJEEB	*

NAJEEB		
RINTO , FIKRIYAH, BAGUS NURUL IMAN, HANIKAH, AHMAD MUNAJIM, SATI, DIANA SETIANA, MIMIN DARMINI		
Morphometric analysis of foramen of Civinini - an anatomical guidance for maxillofacial surgeons SUSHMA.B, KARTHIK GANESH MOHANRAJ, THENMOZHI.M.S	*	
Knowledge, frequency and health hazards of overuse of mobile phone among Chennai population - A questionnaire based survey B.VIVEK BABU, KARTHIK GANESH MOHANRAJ	*	
Autotransplantation of an impacted maxillary canine in a young male - a case report DR BHAT, PROF.DR SENTHILNATHAN PERIASAMY MDS, DR MURUGAIYAN ARUN	*	
Assessment of ns1, igg and igm antibodies in suspected dengue patients SHARMILA R, N.P.MURALIDHARAN	*	
Awareness of different polishing systems available for direct aesthetic restoration in dentistry LASYA GENJI, DHANARAJ GANAPATHY, KEERTHI SASANKA	*	
Assessing knowledge, attitude and practise regarding recurrence of oral mucocele among dental practitioners DR BHAT, PROF.DR SENTHILNATHAN PERIASAMY MDS, DR MURUGAIYAN ARUN MDS	*	
Assessment of knowledge, awareness and practice of surgical guilt among oral and maxillofacial surgeons SNEHA KRISHNAN, SENTHILNATHAN PERIASAMY, ARUN MURUGAIYAN	*	
A survey on use of digital study models in postgraduate orthodontic programs AKSHAY MOHAN, HARISH BABU	*	
Awareness of oral cancer among high school students ASHNA.Y, DHANRAJ GANAPATHY, L.KEERTHI SASANKA	*	
Assessing The Relationship Between The Cervical Vertebrae Maturation Stages And Permanent Maxillary Canine Calcification Stages - A Retrospective Study ANJALI THOMAS, ARAVIND KUMAR SUBRAMANIAN, REMMIYA MARY VARGHESE	*	
Knowledge, attitude and practice regarding toothbrush disinfection among dental students in Chennai: A cross sectional study MANALI BARMA, JAYSHRI PRABAKAR, MEIGNANA ARUMUGHAM INDIRAN, PRADEEP KUMAR.R, SRISAKTHI DORAIKAN	҂	
Mutation and gene expression analysis of Cytochrome P450 Family 1 to decipher the association with HNSCC PADMA N, SMILINE GIRIJA A.S, PARAMASIVAM A, VIJAYSHREE PRIYADHARSINI J	*	
Knowledge and awareness of cad cam surgical guide in digitalization of implants among dental practitioners. KEERTHIKA.S, SUBHABRATA MAITI, JESSY P	*	
Knowledge, awareness and practice on management of lefort III fractures among dental students- a survey PREETHA PARTHASARATHY, DHANRAJ GANAPATHY	*	

Genetic Detection of Pseudomonas spp. and Microbial Quality Assessment in Marine Fish are Available in Local Markets of Baghdad City	*
ALIAA S.A.AL-FRAJI, SUDAD JASIM MOHAMMED, ADIL.T. AL – MOUSAWI	
Bio-psychology Concept of Illness through Premature Ejaculation Mechanism MADE NYANDRA	*
Innovative Work Behavior during COVID-19 for Medical Representatives in the Pharmaceutical Industry: Test of a Moderation Model in Bahrain SAAD DARWISH, UMAIR AHMED, MUNWAR HUSSAIN PAHI	*
A Case of 2019 Novel Coronavirus Infection in a Preterm Infant with Severe Respiratory Failure NENI SUMARNI, LILIA DEWIYANTI, MADELINE HARI KUSMANTO, CIPTA PRAMANA	*
Simultaneous Determination Of Phyllanthin, Hypophyllanthin, And Niranthin In Rabbit Plasma By Lc-Ms/Ms PHAM SON, TRAN LONG THAI, CHUONG NGOC NAI, PHAM THI THANH THAO, NGUYEN DUC TUAN, TRAN VIET HUNG, NGUYEN NGOC VINH	*
Simultaneous Determination of Amlodipine, Losartan, and the Losartan Carboxylic Acid Active Metabolite in Human Plasma by LC-MS/MS CHUONG NAI, NGUYEN VAN TRUNG, TRAN LONG THAI, TRAN VIET HUNG, NGUYEN DUC TUAN	*
Relationship of The Family Health Task Implementation with Motivation a Adherence of Tuberculosis Treatment among Tuberculosis Patients TINTIN SUKARTINI, ALFIATIS SU'UDIYAH, LAILY HIDAYATI	ınd
The Influence Of Students Class Differences On Habits And Knowledge Of Dental And Oral Health ILHAM MUHAMMAD, JAEL SEGAH M.L., FATA ARIESTIA P, TASYA NAFATILA CHALISHA, DHINDA NOVIA, PANDU PUJI HARDINI, YASHICA ALIFIA AMANDA, AULIA RAMADHANI	*
Tocopheronic acid attenuates chlorpromazine induced liver injury in rats targeting oxidative stress and same biochemical markers ATHEER YASEEN, ANEES ABBAS YASEEN AL-FATLAWI	,
Effect of new synthesized compounds of 2-Thiouracil Sulfonamide Derivatives against colon and liver carcinoma cells "in Vitro Study" SAIF M.HASSAN, ASHWAQ NAJEMALDEEN ABBAS AL-JAF, YASMEEN ALI HUSSIEN, SAMIR M.AWAD, MAYSAA ALI ABDULKHALEQ, NAJAH R.HADI	*
Innovit E 60 supplement: effectiveness in poultry feeding VASILY G. FRIZEN, MARINA I. SLOZHENKINA, ZOYA B. KOMAROVA, SERGEI M. IVANOV, TATYANA V. VORONINA, ALISA V. RUDKOVSKAYA, ANDREY V. KULIKOVSKY, DANIIL V. FRIESEN	*
Actual problems of surgical treatment of intraarticular fractures of the distal humerus M.AL ABDULLAH, E.I.SOLOD, N.V.ZAGORODNIY, M.A.ABDULKHABIROV	*
New approaches to osteosynthesis of ankle fractures M.AKRAA , E.I SOLOD, N.V.ZAGORODNIY, M.A.ABDULKHABIROV	
Scientific Process Skills Learning, Biotechnology Materials, and Character Building	*

Candidal Species Seen in Oral Cavity of Children with Type I Diabetes Mellitus DR.SOPHIYA G, DR.DEEPA GURUNATHAN, DR.MEBIN GEORGE MATHEW	*
Evaluation Of Accuracy And Reliability Of Oneceph Digital Cephalometric Analysis In Comparison With Autoceph Digital Cephalometric Analysis AKSHAY MOHAN, HARISH BABU	*
Analysis of emissary foramina in parietal and occipital bone and their clinical implications HARIPRIYA.R , KARTHIK GANESH MOHANRAJ	*
Awareness on computer aided design and its applications among general dentists: a knowledge, attitude and practice study SUBASHRI.A, DHANRAJ GANAPATHY	*
Knowledge and attitude of endodontic treatment of primary teeth among various specialists SUBASHRI.A, GANESH JEEVANANDAN	*
Practice of sterilization of dental burs among dental students N.MOHAMED ARSATH, DHANRAJ GANAPATHY, KEERTHI SASANKA	*
Insomnia among the dental college students ALDRIN A, DHANRAJ GANAPATHY, L.KEERTHI SASANKA	*
Evaluation of laser guided infrared thermometry as an auxiliary tool for pulp vitality assessment-a clinical study. K.AJITH KAMATH, IFFAT NASIM	*
Knowledge And Awareness About Class II Dental Caries Among Dental Practitioners Among The South Indian Population. RINIESHAH R.BASKRAN, MANISH RANJAN	*
Surface Modification of Titanium Dioxide Microparticles Under Ultrasonic Treatment O.A. BUTUSOVA	*
Renewal of Fraxinus mandshurica Rupr. in Mixed Coniferous-broad Leaved Forests of the Southern Far East ANDREY KOMIN, PAVEL ANDREEVICH KOMIN, VLADIMIR NIKOLAYEVICH USOV	*
The Effect of Kebar Grass (Biophtyum petersianum Klotzsch) Extract o the Number of Leydig Cells of Mice (Mus Musculus) Treated with TCDD MILLA NURSADIDA, HANI PLUMERIASTUTI, YENI DHAMAYANTI, WIDJIATI, EPY MUHAMMAD LUQMAN	
The effectiveness of the test plant on account of somatic mutations in leaves of soybean glycine max (I.) Merrill. BITTUEVA MUKHAMATOVNA, BOGOTOVA ZALINA IKHSANOVNA, PARIT ANZOR YURIEVICH, KHANDOKHOV TAKHIR KHAMIDBIEVICH, SABANO RAYA KADIROVNA	
Comparative biological studies, phytochemical screening and GC-MS analysis of some Egyptian Red Sea macroalgae SHIMAA AHMED, AZIZ A. RAHMAN, KHALED N. M. ELSAYED, SAYED A. AHMED	*
The model of interprofessional collaboration practice based on public services in comprehensive emergency obstetric and neonatal care service	*

SULISTYANINGSIH , Y. WARELLA, SUTOPO PATRIA JATI, MEIDIANA DWIDIYANTI	
Design, synthesis, molecular docking and antibacterial evaluation of novel Isoniazid derivatives bearing 1,3,4-Oxadiazole and 1,2,3-Triazol moleties MAZEN JWAID, KARIMA FADHIL ALI, MAYADA HADI ABD-ALWAHAB	*
Factors affecting the quality of life of Thallasemia ß major children MEIYANTI , NOVIA INDRIANI S, EVELINE MARGO, LIE T MERIJANTI S	*
Implementation of Sodium Lignosulfonate (SLS) surfactant from bagasse for enhanced oil recovery process: An observation of laboratory research RINI SETIATI, AQLYNA FATAHANISSA, ARINDA RISTAWATI, SUGIATMO KASMUNGIN, ABDUL HAMID, ASTRI RINANTI	*
High Mobility Group AT-Hook 2 expression is elevated in cervical cance MONICA HARTANTI, ELSHA DWI ANGGUN RACHMADHANY, ITA TAZKIATUL IZZATI MUSTOPA, ELRIAN SYAPUTRA, ELFIRA SUTANTO, GATOT PURWOTO	r *
Organizational-Pedagogical Conditions Of Forming Medical College Students' Professional Competences SYCHEVA VAHITOVNA, REZIDA AKHATOVNA FAHRUTDINOVA, RAIKUL KENESBAYEVNA DIUANOVA	*
Resilience of children with writing disorders SHAMIL SHEYMARDANOV, OLGA SHTERTS, OLGA SHATUNOVA	*
Toxic effects of neurotoxins (Anatoxin-a) purified from blue-green algae Pseudoanbaena limnetica on some organs in laboratory mice (Mus musculus L.) MARWA A. AUBAEED, KASSIM F. ABDULKAREEM, ALAA S.KATHIM, EMALY.A. AL-SULTAN	*
Posterior Segmental Osteotomy Of Maxilla using Piezoelectric device- An Alternative for Vertical Maxillary Excess- A Case Report DR.SUBHASHINI R, DR.ABDUL WAHAB P U	*
Self-Awareness to Undergo Orthodontic Treatment Among Adolescents A Survey PRAVALIKA . DHANRAJ GANAPATHY. KEERTHI SASANKA	;- * ⊚
Prevalence of Maxillary Canine Impaction in Various Types of Skeletal Malocclusion-A Retrospective Study H.SRUTHI, SRIRENGALAKSHMI	*
Awareness on Nipah Virus Among College Students PREETY RAJESH, DHANRAJ GANAPATHY	*
Impact of Brushing Teeth at Night Before Sleep NGOUBINAH PRETTY, DR.DHANRAJ GANAPATHY, L.KEERTHI SASANKA	4 *
Knowledge and Awareness About Uses Of Dental Surveyors Among Dental Students- A Survey KIRAN KANNAN, DHANRAJ GANAPATHY, VIVEK NARAYAN	*
Awareness on Anger Management Among Dental Students M.B.SAI KEERTHANA, DR.DHANRAJ GANAPATHY, L.KEERTHI SASANKA	*
Oral Hygiene Practices Among Preschool Children In Salem SARVASRI T, DHANRAJ GANAPATHY, KEERTHI SASANKA	*

	- 1
The comparison between male and female of infection Cryptosporidium in Baghdad SAFA T.W.HAEEB, ZEID ALSADOON, MUTHANNA NAEEMAH KARAM ALTAEE, BRAA A. ALSHAKIR, HASANAIN SAHIB SALIH, FAISAL ALI LATTEF, RAFAL SALAM KADHIM	*
The Relation Between Fibroblast Growth Factor 21 and Oxidative Stress in Insulin Resistance With Diabetics SAFAA SABAH, THIKRA ALI ALLWASH	*
Radiographic evaluation of interdental bone loss in smoking patients in holy Kerbala city SAMEER HATEM ABDUL HALEEM, SANAA JAMAL MAHMOOD	*
Histopathological study on Aborted Women with Toxoplasmosis THAER ABDULQADER SALIH, NOOR HAMEED HANOUSH, MUNA SALAH RASHID	*
Studying Effect Of Using Drugs of (Clomiphene citrate, Bromocriptine)on physiological & biochemical Parameters in the women have hormone disorder. SARIA NAJI MUHSIN, AYA SAAD YASEN, SINA NAJI MUHSIN	*
HPV 52 most dominant Human Papillomavirus (HPV) genotype in women infected by Human Immunodeficiency Virus (HIV) that get antiretroviral treatment (ART) RISNAWATI, ARIAWAN SOEJOENOES, SUHARYO HADISAPUTRO, MUCHLIS AU SOFRO, SAMSURIDJAL DJAUZI, NOOR PRAMONO, ARI SUWONDO, DENDI DURAHMAN, JULIAN PRATAMA	*
Effects of single and intermittent glucose exposure on hyaluronic acid, heparan sulfate, and syndecan expression in HUVECs cells DEWI INDAH NOVIANA PRATIWI, NIA KANIA, M ARIS WIDODO, KUSWORINI HANDONO	*
Clinical impact of antibiotic sensitivity in patients afflicted with diabetic foot ulcer , DENLIA TINTU ALEX, NAZIYA NAVAS, SAMBATH KUMAR.R, SUMITHA S.K.	*
Diammonium Phosphate and Sucrose Enrichment on Fermentation for Anti-bacteria Activity by Lactic Acid Bacteria DAVID YUDIANTO, ELLYAS ALGA NAINGGOLAN, DHINA APRILIA NURANI WIDYAHAPSARI, ANDITA SAYEKTI, JONI KUSNADI	*
Association between Pregnancy Exercise and Sleep Quality in Second Trimester Pregnant Women YOGA ERLAMBANG ANJASMARA, IRMIYA RACHMIYANI	*
Differences in Hemoglobin and Ferritin Levels in Neonates from Mothers with and without Iron Deficiency Anemia ARNI AMIR, ERYATI DARWIN, AINAL MARDIAH	
Comparison between Effect of Fenitoin and Valproic Acid on Total Cholesterol in Epilepsy FARISA AULIA, YUDHISMAN IMRAN	*
Analysis of LGBT Factors in Religion, Law, Health, Psychology and Community Perspectives in Bukittinggi EVI HASNITA, NURHAYATI, NEILA SULUNG, OKTAVIANIS, MILA SARI, ZURAIDA, DAHLIA MURNI	*

Knowledge, Awareness on Harmful Effects of Smoking Among High School Students - A Survey SUTHARSHAN S, DHANARAJ GANAPATHY, L.KEERTHI SASANKA	*
Sealing Ability of Mta Vs Biodentine In Repair of Furcal Perforation of Primary Molars: An In Vitro Study PAVITHIRAA SANKAR, MAHESH RAMAKRISHNAN	*
Knowledge, Attitude and Awareness of Long Acting Bupivacaine Among Dental Students- A Survey Based Study ILANKIZHAI RJ, DHANRAJ GANAPATHY, SUBHABRATA MAITI	*
Socket preservation with palatal Free Gingival autograft- A Case Report. J.ATHIBAN RAJ, PRIYA LOCHANA GAJENDRAN, THIYANESWARAN NESAPPAN, ABHINAV RAJENDRA PRABHU, SUBHASREE.R	*
An Evaluation of Antimicrobial Effect of Sodium Valproate Against Orodental Pathogens CHAITANYA P, EZHILARASAN D	*
Knowledge Attitude and Practice of Radisection And Hemisection Among Interns and Dental Practitioners HARRITA.S, DHANRAJ GANAPATHY	*
Clinical Evaluation of Pink Esthetic Score And White Esthetic Score Between Natural Teeth And Single Implant Supported Crown In The Ante Maxilla.	rior
VAISHALI PRIYADHARSHINI, PRIYA LOCHANA GAJENDRAN, THIYANESWAREN NESAPPAN, ABHINAV RAJENDRA PRABHU	
Molecular Identification and Phylogenetic Analysis of Rotavirus in Children Suffered from diarrhea under Five Years Old in Thi-Qar Province, of Iraq MOHAMMED N.FENJAN, BASIM A. JARULLAH, SHAYMAA JAWAD ABDULRAHMAN, ALI B. ROOMI	*
A Study of Anti-Fungal Activity for Some Antibiotics Against Aspergillus spp. and Candida spp. in Iraqi patients with Diabetes Mellitus MUATAZ AL-TAEE, AHMED YASEEN AL-TARBOOLEE, WISAM HASAN HADI	¥
Expression Of (CD105) And (VEGF-R3) In Dermoidcyst MUAZEZ ABDIL KHALIQ MALEH, IHSAN ABDULLAH KUMAIL	*
Activity of a novel Selena-diazole derivative compound on primary neuron cells isolation from cortex and hippocampus of 18th day aged fetus of pregnant Wister rat NADHEERAH F.NEAMAH, SHAKER.A.N.AL-JADAAN	*
The response of hypoalbuminemia, hypocalcemia and hypercholesterolemia to regular treatment in a group of pediatric patients with nephrotic syndrome RAID HASHIM, ISRAA NATHIR, NADIA MOHAMMED KHALIL	*
Evaluation Of The Execution Of Precautionary Measures To Diminish The Prevalence Of Covid-19 Pandemic At Al-Nasiriya City Southern Iraq RAWAA ABD	*
The effects of irisin on the transforming growth factor-beta1(TGF-B1) level in type-1 diabetic patients in Thi-Qar province. SAAD H.AL-BADRY, ALI A. AL-KHUZAIY, SHAYMAA A. KHALAF, ALI B. ROOMI	*

Omega-3 Fatty Acids Relieve Dysmenorrhea among Female Senior high School Students WISNU KUNCOROAJI, IRMIYA RACHMIYANI	*	
The Correlation between Homocysteine and Bone Mineral Density by Terminal C – Telopeptide Crosslink Serum Test on Post – Menopausal Women IRMIYA RACHMIYANI, YUDHISMAN IMRAN, DONNA ADRIANI, LILY M	*	
SURJADI, RULLY AYU NIRMALASARI, TUBAGUS FERDI FADILLAH Determination Effect of Probiotic Supplements on the Body Biochemical Markers in Obese Rate SAIF T.JASIM	*	
Phylogenetic Tree of Some Nosocomial Bacteria Isolated from Ramadi Teaching Hospital YASAMEEN HASAN ALI, AYSER ASHOUR KHALAF, FARAH JIHAD QANBAR, SAADE ABDALKAREEM JASIM	*	
Fabrication of novel topical drug loaded elastic membrane vesicles of liposomes as a tool for dermal delivery in effective treatment of psoriasis S.NAGALAKSHMI, V. NIVATHRA, S. SHANMUGANATHAN	*	
A Study To Assess The Prevalence Of Low Back Pain Among Adults At Selected Villages Under Rural Health Training Centre DR.R.POONGODI, MRS. SARKUNA RAJALET.S, SNEHA VARGHESE	*	
Validation Of Tamil Version Of The Anemia Knowledge Questionnaire (AKQ) ARUNA SUBRAMANIAM, SIRALA NALINI JAGADEESH, POONGODI RAMALINGAM, P. SARANYA	*	
The risk of peripheral neuropathy among persons with diabetes residing in selected villages at Thiruvallur district, Tamil Nadu, India R.FAUSTINA PAVITHRA, DR.ARUNA.S, DR. RAJARAJESWARI KUPPUSWAMY	*	
Effectiveness of Structured Breast Self-Examination Teaching Programme Using Breast Simulator on Knowledge and Attitude Among Working Women In Selected Companies SOUNDARYA.G, POONGODI RAMALINGAM, ARUNA SUBRAMANIAM	*	
Compare the effectiveness of neurodynamic mobilization and PNF program in improving sensorimotor function in diabetic neuropathy in lower limbs PETETI SAIRAM, SURESH J	*	
Physiotherapist Perception and Attitude of Treating Transgender NITHYA.M., SURESH.J	*	
ADMINISTRATION HEALTHCARE SYSTEM: Advancing the Knowledge and Skills of Nurses' Professional Working with Family Caregiver of Mental Illness CHAIRUN NASIRIN, ANDRIES LIONARDO	*	
Diastolic Blood Pressure Related to ABI Values Use for Peripheral Arterial Disease Screening in Women Over 50 Years Old LIE TANU MERIJANTI, PUSPARINI, MEIYANTI, ALVINA, M TJAHJADI	*	
Cobalamin and Methylmalonic Acid as Biomarkers of Vitamin B12 Deficiency in Elderly PUSPARINI , ALVINA, LIE TANU MERIJANTI, MEIYANTI	*	

The Beleficiality of Teachers (Compiler of Lord and the Coults of Life	
The Relationship of Treatment Compliance Level and the Quality of Life of Elderly Patients with Hypertension D.I.PERMATASARI, MEIYANTI	*
Promising Preclinical Data to a Possible Antidiabetic Drug RUSUL AHMED TARIQ, BASMA TALIB AL-SUDANI, INAM SAMEH ARIF	¥.
The Miswak (Salvadora Persica) Chewing Stick: Muslim Consumer Behavior Of Halal Oral Hyglene Product SUSILAWATI, TAUFAN BRAMANTORO, DINI SETYOWATI, KEYOLA LAILA OLIVIA	*
Estimate levels of the liver enzymes and serotonin immune localization in the brain of rats administrated orally with sodium benzoate. LEENA ADEEB MEHDI, ALAA MOHAMMAD HASSON	*
Correlation of body mass index and vo2 max in physiotherapy students MALARVIZHI D, METHA K S	¥
Comparation Pm10 Distribution Between Control Sites And Research	
Site In Rawang City, Selangor MOHD HAIRY IBRAHIM, MOHAMAD IHSAN MUHAMAD ISMAIL, NOR KALSUM MOHD ISA, SHARIF SHOFIRU SHARIF ALI, MOHD HISHAMUDIN CHE OMAR, MIFTACHUL HUDA, ANDINO MASELENO	*
Flood Risk Assessment in Beaufort, Sabah, Malaysia ADI JAFAR, NORDIN SAKKE, CHONG VUN HUNG, MOHAMMAD TAHIR MAPPA, MOHD HAIRY IBRAHIM, MOHD HASHIQ HASHIM, MIFTACHUL HUDA, ANDINO MASELENO	*
Investigation Of Water Quality Level In Behrang Forest Reserve Catchment, Perak MOHD HAIRY IBRAHIM, SUMAYYAH AIMI MOHD NAJIB, NOR KALSUM MOHD ISA, KAMARUL ISMAIL, MOHD HASHIQ HASHIM, MIFTACHUL HUDA, ANDINO MASELENO	*
Defective ground hexagonal patch for Biomedical ap-plications. MANJULATHA TELKAPALLI, DR. K.CH. SRI KAVYA	
Psychology of the Students During, Pre & Post Covid-19 B.LAKSHMANA SWAMY, P. N. V. BALA SUBRAMANYAM, MOHAN AWASTHY, MOON BANERJEE	*
The Knowledge of Pregnant Women about the First 1000 Day Life	
Program TRI SUNARSIH, DIAH AMANTA KARUNIA DEWI, ENDAH PUJI ASTUTI	*
Pharmaceutical Analysis of Drakshadi Syrup - A Polyherbal Ayurvedic	
H <mark>ematinic</mark> ABOLI PATIL, RAJANISH METI, SWAPNIL CR	¥
Helicobacter Pylori and Recent Ischemic Stroke: Is there a	
Relationship? AHMED KHALID ALDHALMI, LAITH ALDABBAGH, AMMAR JABBAR HAMAD, SADIQ J. AL-MUHANA, HAYDER K. HASSOUN, MOHAMMED DHAMIN ALAREEDH, AHMED ALMUDAFER, JABER HATIF JABER	¥
Single – Center Assessment of Short-Term Morbidity Associated with Ureteric Stone ASRAA TAHA HAMED, ALI HADI SABHAN	¥
Knowledge perspective and use of unconventional complementary and alternative therapy among diabetes patients attend diabetic center in Aldiwanyia teaching hospital	*

Anti-Diabetic and Anti-Hyperlipidemic Evaluation of Celtis philippensis Blanco on Albino Wistar Rats SUJITH THOMAS, ROHIT SARASWAT, B ARUL	*	
Biosynthesis of Silveryanoparticlesa'producing"erhizopus Stolonifer and Study It Antifungal Activity on Candida Albicans Isolated from Subclinical Bovine Mastitis. SUDAD JASMMOHAMMED, SHAIMAANABHAN YASSEIN, JASIM MOHAMMED KARHOOT	*	
Reproductive Health Status of Irula Tribal Women in India KM ASHIFA	*	
Investigating of Patient Complaint Handling Risk Management in Hospital LUH GEDE DEWI IDAYANTI, IDA BAGUS RAKA SUARDANA, GEDE SRI DARMA	*	
Biochemical Biomarker Disorder Potential to Identify COVID-19 Patients in Iraq ALI A.H.ALBAKAA, THAER ALI HUSSEIN, WESSAM R.N. MOHSEN	*	
Status of some selected Trace Elements Levels and lipid profile in Ischemic heart disease patients with type 2 Diabetes Mellitus , ABD ELGADIR A.ALTOUM, HANI M. MOHAMED, AHMED L. OSMAN, MARWAN ISMAIL, PRAVEEN KUMAR KANDAKURTI, ASAAD MA. BABKER	*	
Effect of oropharyngeal exercise on snoring and quality of sleep among obstructive sleep apnea patients SATHYA PRIYA.S, D. ANANDHI	*	
Design And Evaluation Of Medicated Dermal Patches Of Proton Pump Inhibitor-Esomeprazole M.R.SHIVALINGAM, ARUL BALASUBRAMANIAN, KOTHAI RAMALINGAM	*	
Biochip test systems in differential diagnosis of metastatic lymph nodes. SEIDALIN N.K., BENBERIN V. V., SHANAZAROV N. A., TULEUBAEVA A. A., SATAEVA ?. S, TOKHPANOVA N. A., ISABEKOVA A. M.	*	
Research on the impact of the covid-19 pandemic on global economic processes NATALIA A.PRODANOVA, DMITRY O. BOKOV, LYUDMILA V. SOTNIKOVA, LYUDMILA N. KORSHUNOVA, NATALIA O. VIKHROVA, NIKOLAY N. NIKULIN	*∞	
Awareness On 5 Axis Milling Machine Among Undergraduate Dental Students- A Survey AMIT SINGH, REVATHI DURAISAMY, DHANRAJ GANAPATHY	*	
Knowledge And Awareness Of The Importance Of Daily Intake Of Folic Acid Among Women Of Child Bearing Age AMRITHAASHRI.S, M.JEEVITHA, PREETHA.S	*	
Estimation Of Fluoride In Ground Water In Thoothukudi District, Tamil Nadu,India LALITHA CHELLAPPA, PRADEEP KUMAR RATHINAVELU	*	
Assessment Of Salivary Ph In Patients With Oral Submucous Fibrosis T.N.UMA MAHESWARI, DHANVANTH	*	
Knowledge And Awareness About Effects Of Smoking On Oral Health Among General Population - A Questionnaire Study	*	

ATHMAR HAMZA KHUTTAR, HASSAN RAJI JALLAB	
*	_
Microbiology and Drug Sensitivity Pattern for Patients with Chroni Otitis Media in Aldiwanyia Teaching Hospital BASSAM ABDULAMEER MOHSEN, ALI ABDULAMEER JWAD	c *
Prevalence of anemia in patient with chronic heart failure attending Diwanyiah Teaching Hospital HASSAN RAJI JALLAB, MANAR ABBASS KADHIUM	اA و بر
Sociodemography and Clinical Features of Psoriasis in Patients Attending Dermatology Clinic in Al Diwaniyah Teaching Hospital HASSAN RAJI JALLAB, NUHA JABBAR DABBI	*
Prevalence and Risk Factors of Abortion Among Patients Attendin Maternity and Children Teaching Hospital in AL-Diwaniyah-Iraq YASAMIN HAMZA SHARIF, RANA MOHAMMED HASSEN	g -X
Predictive Value of Estimated Serum Uric Acid in Patients with Act Coronary Syndrome in AL-Diwaniyah Teaching Hospital ALAA HADI ALESSAMI, ZAHRAA ADNAN MOHAMMED	ite -}
A new stage in the development of the chemical and pharmaceutic industry during transition to the knowledge economy ANDREY P.GARNOV, VICTORIA YU. GARNOVA, ELENA V. ZAKHARONATALIA A. PRODANOVA, NADEZHDA P. TISHKINA	•
MILA in teaching Orthodontics DR.DEEPAK NALLASWAMY.V, DR.M. SUBHA, DR SHANTA SUNDAR ASHWIN MATHEW GEORGE, DR ARAVIND KUMAR, DR HARISH BA DR SARAVANA DINESH, DR SUMATHI FELICITA, DR RAVINDRA JAI NAVANEETHAN, DR ARVIND SIVAKUMAR, DR SRIRENGALAKSHMI NAVEEN KUMAR, DR REMMIYA MARY VARGHESE, DR NIVETHIGA.	BU, N, DR 🖥 DR
The Impact of Using Antibiotic Drugs in Pediatric Dentistry HARUN ACHMAD, SARINA, DMITRY O. BOKOV, YUNITA FEBY RAMADHANY, EVGENIY V. KIRICHENKO, ALEXANDER MARKOV	3
A turbidimetric method for the quantitative determination of cyproheptadine hydrochloride in tablets using an optoelectronic detector based on the LEDs array JALAL JEBER, NAGHAM S. TURKEY	3
Molecular Serotyping and Genotype Variation of Escherichia coli Isolated from Urinary Tract Infections AHMED KURDI, ADNAN HAMAD AUBAID	*
Evaluation of Bacteriological Profiles and Antibiotic Sensitivity Par in Children with Urinary Tract Infections KOTHAI.R., PRATHIBA.M, ABINAYA.M.M, AKSHAY.M, ALISHA GEOR ANISHA GEORGE, ARUL.B	9,
Acute and Subacute (28-Day) Toxicity Assessment of Ethanolic Ex of Seeds of Asteracantha longifolia Nees (Linn) MANIVANNAN.E, KOTHAI.R, ARUL.B	tract
Ethnopharmacological Review on Cassia marginata Roxb ARUL.B , KOTHAI.R	*
A Prospective Study of Clinical Characteristics of Chronic Kidney Diseases in a Tertiary Care Hospital, Salem NIVETHA R. BALASUBRAMANIAN ARUL, RAMALINGAM KOTHAI	Ą

NIVETHITHA.R , ARVINA RAJASEKAR		ĺ
Knowledge, Awareness and attitude of clinicians on incidence of undercuts in edentulous patients - a survey SUHAS MANOHARAN, SURESH V	*	
Antimicrobial Activity Of Copper Nanoparticles Biosynthesized Using Dried Ginger SABARITHA.A, M.JEEVITHA, PREETHA.S, S.RAJESHKUMAR	*	
Tobacco Use Among Teenagers In Chennai- A Survey Of Initiation, Prevalence, Knowledge And Attitude SHEBI S, MEBIN GEORGE MATHEW	*	
Knowledge And Awareness On Personalised Medicine Among Dental Students SHEEFAA M.I, M.JEEVITHA, PREETHA.S	*	
Association Of Obesity And Dental Caries Among Young Adults A.SHIVAPRIYA, A.SHIVAPRIYA, M.JEEVITHA, S.PREETHA, M.P.BRUNDHA	*	
Knowledge And Awareness Of Anaphylaxis Among Dental Undergraduates FAAZILA FATHIMA, DHANRAJ M GANAPATHY	*	
Knowledge and awareness of cleft lip or palate among women in general population HEMANTH N. M. JEEVITHA	*	
Awareness On The Effects Of Pollutants In The Marine World Among College Students INDUMATHI M, VISHNU PRIYA.V, GAYATHRI .R	¥	
Comparison Of Surface Characteristics And Compressive Strength Of Tooth Coloured Self Cure Resin To Modified Self Cure Resin Using Glass Impregnated Fibres JOSHINI SHANMUGAM, SURESH V	*	
Prevalence of gingival pigmentation patterns and its correlation with gingival phenotype and gender in an Indian population KADAMBARI SRIRAM, DR.KAARTHIKEYAN G	*	
Knowledge And Awareness On Mouth Ulcers Among Dental Students-A Questionnaire Based Survey KEERTHANA BALAJI, DHANRAJ GANAPATHY, KIRAN KUMAR PANDURANGAN, ASHOK VELAYUDHAN	*	
Effect Of Violent And Non Violent Video Games On Blood Pressure And Pulse Rate Among College Students M.LAKSITA , M.JEEVITHA, S.PREETHA	¥	
Knowledge And Awareness Of Dry Eye Syndrome Caused Due To Prolonged Usage Of Smartphones Among The General Public MANOJ ARAVINDAN, M.JEEVITHA, PREETHA.S	*	
Knowledge And Awareness Of Visual Fatigue On Usage Of Devices With Retina Display And Oled Display NAZ RAJ, M.JEEVITHA, PREETHA.S	*	
Free Radical Scavenging Activity Of Iron Nanoparticles Synthesized Using Dried Ginger NAZ RAJ, M.JEEVITHA, S.RAJESHKUMAR, S.PREETHA	*	
		П

Electrosurgery In Dentistry – A Review NURUL BINTI, DHANRAJ GANAPATHY, REVATHI DURAISWAMY	*	
Morphometric Analysis Of Occipital Triangle In South Indian Dry Skulls JAYADHARANI.C , DINESH PREMAVATHY		
Comparison Of The Effect Of Zumba And Aerobics In Controlling Blood Pressure In The Hypertensives JERUSHA PACKYANATHAN, DR.PREETHA S, DR.LAVANYA PRATHAP	♣	
Orthodontic Treatment Need Among Children Reporting To A Private Dental Hospital NURUL BINTI, DHANRAJ GANAPATHY, REVATHI DURAISAMY	*	
Full Mouth Rehabilitation Of A Bruxer With Severely Worn Dentition Restored With Cad/Cam Fabricated Crowns -A Case Report With 2 Years Follow Up AMAN MERCHANT, DHANRAJ M GANAPATHY	*	
Knowledge, Attitude And Practice Among Dentists Regarding The Custom Made Cast Post And Core A AHAMED, MANISH RANJAN	*	
Knowledge, Attitude And Practice Regarding Tooth Jewellery Among Dental Students And Dental Professionals In Chennai- A Cross Sectional Study LALITHA CHELLAPPA, JAYASHRI PRABAKAR, MEIGNANA ARUMUGHAM INDIRAN, PRADEEP KUMAR.R, SRISAKTHI DORAIKANAN	*	
Computational Approach Towards Detection Of Functional Pathogenic Mutations In Dix-1 Gene And Its Possible Association With Tooth Morphogenesis. R. BHARATHI, A.S. SMILINE GIRIJA, A.PARAMASIVAM, J.VIJAYASHREE PRIYADARSHINI	*	
Knowledge And Awareness Of Effects Of Fenugreek Seeds On Overall Health On General Population SURYA SITARAM, M.JEEVITHA, PREETHA.S	*	
Audiovisual Modelling - An Efficient Method For Reducing Anxiety In Children Undergoing Digital Panoramic Radiograph ABARNA JAWAHAR, G.MARAGATHAVALLI	*	
Research Of Biotechnological Properties Of Microorganisms- Antagonists IRINA S.WILENTYEVA, LYUDMILA K.ASYAKINA, LYUBOV S. DYSHLYUK, NATALIA S. VELICHKOVICH, LEV A. OSTROUMOV	*	
Analyzing the Civil liability arising from the production of substandard drugs(in Iranian legal system and Jurisprudence) , , EHSAN ALIAKBARI BABOOKANI	*	
Knowledge Attitude and Practice on Digital Impression in Dentistry Among the Dental Students VAISHNAVI SIVAKALI SUBRAMANIAN, DHANRAJ GANAPATHY	*	
Mare's Milk As A Sport Nutrition B.BIMBETOV , N.SHANAZAROV, A.ZHANGABYLOV, S.AITBAEVA, A.BAKYTZHANULY	*	
Clinical Model Machine Learning for Gait Observation Cardiovascular Disease Diagnosis	*	

VENKATESH MANNEM, SWARNA KUCHIBHOTLA	
Hospital Management System Using Flask V.TEJU , K.V.SOWMYA, C.YUVANIKA, P.SAI KUMAR, T.BALA DURGA SAI KRISHNA	*
Detection of Abnormalities in COVID-19 Infected Human Respiratory System using Accelerometer with the aid of Machine Learning , K UDAY KIRAN, SHAIKH SHAKEELA, D KALYAN, Y MADHU, G SAI CHAITANYA, G EKANATH REDDY	*
Synthesis, structure, Optical and transport properties of Cu-doped CeO2nanoparticles VENKATESWARARAO JILLEPALLI, G.SUBRAHMANYA SASTRY	
Knowledge And Awareness Of Sleep Disorders Among Dental College	
Students TRISHA.S., M.JEEVITHA, S.PREETHA	*
Synthesis of Metal Oxide Nanoparticles and Formation of Nanostructured Layers on Surfaces under Ultrasonic Vibrations , , YU.V.IONI	*
Study of Microparticles Surface Modification by Electrokinetic Potentia Measuring YU.V.IONI, A.ETHIRAJ	⊪ *
Effect of Ultrasonic Treatment on Properties of Aqueous Dispersions o Inorganic and Organic Particles in Presence of Water-Soluble Polymers YU.V.IONI	
New Tailor-Made Polymer Stabilizers for Aqueous Dispersions of Hydrophobic Carbon Nanoparticles YU.V.IONI, A.ETHIRAJ	*
Woodlands as a tool for actively managing the micro-climate of	
agrophytocoenosis. OLGA V.RULEVA, GLEB A.RULEV, ALEKSANDR S.RULEV	
3-D Printing as A Tool for Applying Biotechnologies in Modern Medicin HARUN ACHMAD, ARNI IRAWATY DJAIS, ELENA G.PETRENKO, MARKO ALEXANDER, VIKHAREVA LARISA, AMINUDDIN PRAHATAMA PUTRA	
Analysis of Nutritional and Antioxidant Contents in Cuttlefish Curry (Malaysia) and Cuttlefish Gulai (Indonesia) MAZARINA DEVI, BUDI WIBOWOTOMO, LAILI HIDAYATI, HASHIM FADZI, ARIFFIN	L
Investigating of Patient Complaint Handling Risk Management in Hospital LUH GEDE DEWI IDAYANTI, IDA BAGUS RAKA SUARDANA, GEDE SRI	¥
The Influence of Leader Commitment on the Quality of Financial Statements and Its Impact on the Performance Accountability of BLUD	
Hospitals in West Java Province RATIH PUSPITASARI, WINWIN YADIATI, SRIHADI WINARNINGSIH, IRIYADI	₩
Application of UV Spectrophotometric Methods in the Simultaneous Analysis of Amilodipine besylate and Celecoxib AARTI S.ZANWAR, DHANYA B.SEN, MARGI K.SHAH, BINAL KUBER, KRUSHITA R.PATEL, PRACHI PATEL, ASHIM K.SEN, A.K.SETH	
Clinical Pharmacist involvement in Evaluation and Management of Dru Interactions at CriticalCare Unit HEMRAJ SINGH RAJPUT, HETAL PANDYA, NIRMAL V SHAH	g *
Design, Development And Characterization Of Promethazine Hcl Orodispersible Tablet SHAH DHIREN P, PATEL SARANGKUMAR M	*
Simultaneous Assessment of Aliskiren Hemifumarate and Valsartan fro	
Pharmaceutical Dosage Form by three simple UV Spectrophotometric Methods	m it's
Methods ASHIM K.SEN, DHANYA B.SEN, AARTI S.ZANWAR, RAJESH A.MAHESHI R.BALARAMAN	
Methods ASHIM K.SEN, DHANYA B.SEN, AARTI S.ZANWAR, RAJESH A.MAHESHI	WARI, ietric
Methods ASHIM K.SEN, DHANYA B.SEN, AARTI S.ZANWAR, RAJESH A.MAHESHI R.BALARAMAN Simultaneous Assessment of Alogliptin Benzoate and Pioglitazone Hydrochloride in Combined Tablet Dosage Form by UV Spectrophotom Methods DHANYA B.SEN, ASHIM K.SEN, R BALARAMAN, RAJESH A. MAHESHWA	WARI, ietric
Methods ASHIM K.SEN, DHANYA B.SEN, AARTI S.ZANWAR, RAJESH A.MAHESHI R.BALARAMAN Simultaneous Assessment of Alogliptin Benzoate and Pioglitazone Hydrochloride in Combined Tablet Dosage Form by UV Spectrophotom Methods DHANYA B.SEN, ASHIM K.SEN, R BALARAMAN, RAJESH A. MAHESHWA AARTI S.ZANWAR Prediction of the potency of active compounds in pasak bumi root as the treatment for prostate cancer through phosphatase and tensin homolog (PTEN) pathway EKA YUDHA RAHMAN, KUSWORINI KUSWORINI, MULYOHADI ALI,	WARI, netric

A.SAMPATH DAKSHINA MURTHY, T.KARTHIKEYAN, B.OMKAR LAKSHMI Analysis of Mathematical Model of Support Vector Machine Techniques for early Prediction of Medical Diseases , PAMULA RAJA KUMARI, POLAIAH BOJJA, ANAND GALLA, RANA

Deep Learning Methodology for Recognition of Emotions using

Acoustic features
VENKATESH MANNEM, SWARNA KUCHIBHOTLA

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ALI A.H.ALBAKAA, THAER ALI HUSSEIN, WESSAM R.N.MOHSEN
Differences in the Effectiveness of Warm Compresses with Water Tepid
Sponge in Reducing Fever in Children: A Study Using a Quasi
Experimental Approach
RISKA HEDIYA PUTRI, YETTY DWI FARA, RUSMALA DEWI,
KOMALASARI, RIONA SANJAYA, HAMID MUKHLIS
                                                                                     X
Factor Analysis of Third Trimester Pregnant Women Readiness in
Preparing for Childbirth: A Cross-Sectional Study
HAMID MUKHLIS. EVA YUNITASARI, HELLEN FEBRIYANTI, NUR ALFI
                                                                                     ×
FAUZIAH, MARGARETA RINJANI, RISKA HEDIYA PUTRI
Prenatal Education of Personal Human Development in Covid-19
Pandemic
MUHAMMAD SADRI, RIA NORFIKA YULIANDARI, LILIANA PUSPA SARI,
ANI CAHYADI, WINDA MAOLINDA
Face and neck skin anatomical and aged-related features detection with
ultrasound technique
                                                                                     ×
OMURZAKOVA ALIYA TURATBEKOVNA. IZRANOV VLADIMIR
ALEKSANDROVICH
Effect of Plasma Discharge in Liquids on Microbiological Objects S.E.DIMITRIEVA ,
Experimental Study of Water Sterilization in Flow by Acoustic Plasma
, S.E.DIMITRIEVA
Humanistic and Mental Health Behaviorism in Shaping the Learning
Process in Covid-19 Outbreak
MOH.MAHBUB, ACHMAD SYARIFUDIN, AKHMAD ANWAR DANI,
                                                                                     ¥
SYAFRIZAL, RATNA DEWI
A Village Health Center Budgeting in the Good Local Governance during
Covid-19 Pandemic
SRI HANDINI, IKA MAYA SARI, AZRI RANUWALDY SUGMA, TUTIK
YULIANI. FEBRIANT\
Student Mental Health Character in Covid-19 Situation
NAZARUDIN, JOLANDA TOMASOUW, AHMAD ZAINURI, ELY TRIASIH
RAHAYU, ALAN ALFIANSYAH PUTRA KARO KARO
Colonialism, Political Identity, Zendeling: Management of Social Problems of Health, Disease and Medical Care during the Colonial
                                                                                     ×
Period in Bali: The Netherlands Indies 1908-1942
I NYOMAN WIJAYA
Use Of Sea Cucumber Extract As An Alternative Treatment Of
Inflammation By Chronic Periodontitis
HARUN ACHMAD. I MARDIANA ADAM, TRISANTOSO REZDY ASALUI,
HULDANI, BAYU INDRA SUKMANA, AMINUDDIN PRAHATAMA PUTRA
Mindfulness Based Cognitive Therapy to Psychiatric Resident of Udayana University: Sanglah General Hospital, Denpasar I PUTU DHARMA KRISNA AJI, COKORDA BAGUS JAYA LESMANA, NI KETUT SRI DINIARI, LUH NYOMAN ALIT ARYANI, GUSTI AYU INDAH
ARDANI, NI KETUT PUTRI ARIANI, ANAK AYU SRI WAHYUNI, LELY
SETYAWATI, IDA AJU KUSUMA WARDANI
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Biochemical Biomarker Disorder Potential to Identify COVID-19 Patients in

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                                                                            HADI ALI .
                                                                            k Factors
                                                                            LJANTO
                                                                            A Basic Policy
to Decrease Population Fertility in Central Java Province
                                                                                                  ×
SRI WINARNI, MARTINI MARTINI, NAJIB
Consumption of Ginger Reduces Menstrual Pain in Young Women
DAINTY MATERNITY, RATNA DEWI PUTRI, YULISTIANA EVAYANTI,
WIRA UTAMI, AGUSTINA RENANINGSIH, YATSUKO PURNAMA
The Effect of Tomato Extract Supplementation to Interleukin-17 Serum
Level in Women with Melasma
                                                                                                  ×
LIZA AFRILIANA, LISYANI BUDIPRADIGDA, KIS DJAMIATUN
An Ethno botanical and Pharmacological Review on Phyla nodiflora GHANSHYAM R. PARMAR, SUNIL B. BAILE, KUSHAL GOHEL, ASHISH SHAH,
SHIVKANT PATEL, AVINASH K. SETH
Risk Typology For Peer-To-Peer Lending In A Financial Architecture
Transformed By Digitalization And The Epidemiological Situation
MAKSIMOVA TATIANA PAVLOVNA, ZHDANOVA OLGA ALEKSANDROVNA,
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BONDARENKO TATIANA GRIGORIEVNA

Prolongation of QTc interval associated with Drugs Used in Management of COVID 19 MUZAKKIR AMIR, IRAWATY DJAHARUDDIN, HARUN ACHMAD, MIRZA SYAFARYUNI, L TRI	*
Effects of Sulforaphane in brain ischemic reperfusion injury in rats , MUNTADHER HAMEED THWAINI, AHMED R. ABU RAGHIF, NAJAH R.HADI	*
Impact of Leptin Hormone on Cardiac Function in a Sample of Iraqi Population with cardiovascular disease BASIM ABD ALI SAEED, HUSSEIN A. ALSALKHI, SAMET ELIAS KASIM, AHMED N. RGEEB, QASIM MOHAMMED TAHER	*
The role of ultrasound in the diagnosis of non-traumatic acute abdom SAMER MAKKI MOHAMED AL-HAKKAK, SAAD AB-RAZQ MIJBAS, ALAJ ABOOD AL-WADEES	
Spirometric Changes in Patients with Angiotensin Converting Enzym Inhibitors (ACEI) Induced Cough FALAH ABDULHASAN DELI, SAMET ELIAS KASIM, SAMIR T. ABEID, KADIM EDAN AFLOK, IMAN JABBAR KADHIM	e *
Formulation, optimization and in vitro evaluation of lovastatin drug loaded solid lipid nanoparticles GANNIMANI VEERABHADRA RAO, GADELA VENKATA RADHA, M.KRISHNAJI RAO, S.BRITO RAJ, K.BHASKAR REDDY	*
Covid-19 Pandemic and Application of Disaster Management Act, 200 Promises and Pitfalls M.Z.M.NOMANI, REHANA PARVEEN)5: *
Study of some immunological markers (IL-8 and TGF-ß1) and it's relation with Pneumocystis jirovecii infections DHAY A.AZEEZ, ADNAN H. AUBAID, GHADA B ALOMASHI	*
Clinical And Epidemiological Characteristics Of Patients With Covid- OBLOKULOV A.R, NIYOZOV G.E	19 🚜
Ways Of Optimization Of Comprehensive Treatment Of Purulent Diseases In Patients With Diabetes Mellitus KHUSANBOY MUSASHAYKHOV, KAMAL MIRZAEV, RASULJON ABDULLAEV, DILSHODJON AZIZOV, SANJARBEK UMURZAKOV, BAKHTIYORJON MATKARIMOV	*
Research of economic aspects of national projects' allowance of cardiac surgery in order to reduce heart failure in children TATIANA GRIGORIEVNA BONDARENKO, NATALIA ALEKSEEVNA PRODANOVA	*
Surgical management of congenital hiatal hernia: A retrospective constudy, single-center experience LAITH FATHIF. SHARBA, SAMER MAKKI MOHAMED AL-HAKKAK, FIRA SHAKER MAHMOUD AL-FAHAM, JALAL JAAFAR ABDUL HUSSEIN	Q.
Analytical Method Development and Validating the Estimation of Pregabalin in bulk and its Formulation using RP-HPLC BIRENDRA SHRIVASTAVA, SAI RAJESH KOLLAPUDI, DINAKAR A	*
Effective Communication Models to Improve the Animal Cooperatives Performance in Bali-Indonesia GEDE SUARTA, NYOMAN SUPARTA, I GST NYM GDE BIDURA, BUDI RAHAYU TANAMA PUTRI	*

Colorectal Cancer in Semr	FARD, ÉLHAM ZIAEIFAR, SHAGHAYEGH	*
Village, India	g Primary School Children In Mudichur MONISHA.R, P.KARTHIKEYAN	*
	tion program for preschool children with on disorder: A randomized controlled trial MONISHA.R, R.PRASANNA	*
coordination disorder at 12	Skills in Children with Developmental 2-Month Follow-up MONISHA.R, BALAJI CHINNASAMI	*
Pilot Study	Integration Therapy In Childrenwith Autism: A MONISHA.R, M.SATHYAMOORTHY	*
	mobility Syndrome and its association with on Disorder (DCD) in Indian context MONISHA.R, G.GAUTHAM	*
Examining the cognitive portion of the Coordination Disorder in In GANAPATHY SANKAR.U, M		*
Performance For Children (Dcd) In Indian Context	otor Integration Skills On Handwriting With Developmental Coordination Disorder MONISHA.R, T.NEDUNCHERALATHAN	*
	visual-motor integration and handwriting Indian children at the age of 4–6 years MONISHA.R, V.YUVARAJ	*
		*
	al-motor integration and manual dexterity in tal coordination disorder in Indian Context	*
	tegy Of Mathematical Planning Of The Experim ry Substances For A Gel Based On Dry Extract /A, F.KH.MAKSUDOVA	
Object Tracking	Efficient Segmentation Technique for Multiple R.ANNA SARO VIJENDRAN	
Healthcare Multiband Appl	rcular Spike Shaped CPW Fed Antenna for lications A, C SUBBA RAO, LANKA MADHAVI DEVI	
Applications	ctal Antenna for GPS, ISM and Medical band SUBBA RAO, SWATI LAKSHMI BOPPANA	*

Colony-stimulating factor 1 (rs2050462) and Cluster of differentiation 44 (rs13347) Polymorphism, Their Association With Risk of Kidney stone in Iraqi Populations. MANAL M.KADHIM, HENADI N. MOHAMED	*
Title: MRI to examine cardiovascular toxicities of cancer treatment MOHAMMED ALSHEHRI, LEWIS MORGAN ABAY	*
Title:EffectofCOVID19ontheInterventionalRadiology:AStatisticalAnalysis FAHADMOHAMMEDALSHEHRI, LEWISMORGANABAY, M.D	*
Association of vitamin D and dental caries in children in Basra HIYAM SALAH AHMED, GHASSAN S.AHMED, ZAINAB ABDULKAREEM MAKTOOF	*
A Survey Study Of Lecturer's Performance About Work From Home During The Pandemic Of Covid-19 MULYANINGSH , DETY MULYANITI, YONY DJOGO, RESTY ISMAWANTI, AGUS IWAN MULYANTO, SUHARTONO	*
A Case Of Teen Procuresses Empowerment Modelthrough Distance Learning Education During The Pandemic Of Covid-19 SUHARTONO, CICIH MURNIASIH, FARIDA YULIATY, ELLY RESLY RACHLAN, DETY MULYANTI	*
Privacy-PreservingCloud-AssistedSecure Authentication For E-Health Medical Data Maintenance DR.C.MENAKA, PRAVEEN KUMAR V	
Pharmacovigilance Based Artificial Intelligence And Machine Learning In Software Testing - An Empirical View ESHETU DERESU, VELMURUGAN.L, MANOHARAN.S	*
Accurate Recognition and Isolation of Brain Tumor Evidences from Medi MRI Images using Image Recognition Guarantee , DEVI KALA R, DR GLADIS D	cal
Representation of Women with Medical Defined Disability in Malayalam Cinema MEERA U MENON, SREENA K	*
On preparation to the enactment of the TR EAEU 041/2017 "On safety of chemicals" as a step towards globalisation and development of digital economics KIRILL SKOBELEV, DARIA ZAGORSKAIA	*
Preparation, Characterization and Biological Study of some New Transiti Metal Complexes Derived from Imidazole and Thiazole MITHAQSAEED MOHAMMED, HUSSIN SALIHMAHDI	on
Nutritional Status of Children Ages 6 - 59 Months with Anorexia Who Examined at National Institute of Nutrition NGUYEN TRONG HUNG, PHAM THI THU HUONG, TRAN THI TRA PHUONG, NGUYEN THI LAM, NGUYEN THI LUONG HANH, NGHIEM NGUYET THU, NGUYEN HONG TRUONG, LE DANH TUYEN	*
Dose Early Detection of Hypertension through the Early Detection of Hypertension Program or Inclusion of Mobile Communication Improve Hypertension Outcomes in the Attendees of Primary Healthcare Centers in Najaf Governorate LAITH ALDABBAGH, AHMED KHALID ALDHALMI, ZAHRAA ABED ALWEHAAB	*

An real and accurate brain diagnosis process on mri brain images using enr machine learning \$\mathcal{X}\$ SRINIVASARAO GAJULA, V. RAJESH
A real and accurate MacGyver based Medical doctors Face emotion Recognition with GoogleNet Deep learning technique *B.KANAKA DURGA, DR. V. RAJESH ** ** ** ** ** ** ** ** **
Mathematical Three - Compartment Model Analysis of Cholesterol Transport in Human and its Cardiovascular Related Dysregulation RAMANAMOORTHY KANDULA, RUPALI S. JAIN, SANDHYA KANDULA, B. SURENDRANATH REDDY
Blending Learning: Enhancing Reading Skills through Virtual Classroom during COVID-19 pandemic DR. GOMTAM MOHANA CHARYULU, DR. SHARADA ALLAMNENI, DR.M LATHA, BHARATH SAMISHETTI, K SAIKUMAR
Role of community development on nation building: case study of mykasih entrepreneurship program among indian community in malaysia MAHAGANAPATHY DASS, SARJIT S. GILL, PUVANESWARAN KUNASEKARAN
Effect of COVID-19 on Cancer: With Special References to Liver Cancer GHASSAN SALAH AHMED, AHMED S. ABDUL JABBAR, MURTADHA A. JEBER, H. N. K. AL-SALMAN, FALAH HASSAN SHARI, QUTAIBA A. QASIM, HUSSEIN H. HUSSEIN
Insilico docking studies, Synthesis and Characterization on Nitrogen and Oxygen Containing Heterocyclic Compound (1,3,4 –Oxadiazole) with promising Antimicrobial and anti-inflammatory activity: Invitro&invivo. DANIEL KRAT
The Russian Covid-19 Pandemic Takeaways: An Artificial Disaster, Or A Man-Made Crisis?
VLADIMIR VELIKOROSSOV, MAKSIM MAKSIMOV, EVGENIY GENKIN, NATALIA PRODANOVA, ANATOLIY KOLESNIKOV, ONA GRAZYNA RAKAUSKIENE
In vitro evaluation of antimicrobial activity and estimation of Epicatechin from the fruit extract of Prunus armeniaca L using HPTLC technique LAKSHMI THANGAVELU
Association of Epstein–Barr virus Detection with Histopathologic-prognostic Findings among Sudanese Breast Cancer patients USRA E.ABDALAH, MANAR G. SHALABI, ABOZER Y. ELDERDERY, ALBADAWI ABDELBAGI, HATEM MOHAMED, ASAAD MA. BABKER, ANASS M. ABBAS
Knowledge and awareness on oral hygiene status among blacksmiths HENA MARIAM FATHIMA, DHANRAJ GANAPATHY, SUBHASHREE ROHINIKUMAR
Knowledge and awareness of brushing habits among leprosy patients MANYA SURESH, DHANRAJ GANAPATHY, VINAY SIVASWAMY
The Pharmaceutical and Chemical Issues and Language Documentation on Oil Palm (Elaeis Guineensis Jacq) and Their Contribution to Agro-Linguistics
SAWIRMAN SAWIRMAN, YESSY MARKOLINDA The Concept of Tanosil (Sexually Transmitted Infections) or HIV / AIDS
Transmission and Criminal Liability Issues

		_
AZIZAKHON AVAZXONOVNA ALLANOVA		ĺ
Potential Endophytic Bacteria Isolates Producing IAA from West Sumatera to Improve the Growth of Oil Palm (Elaeisguineensis Jacq.) at Main Nursers (ROVER, RENI MAYERNI, YULMIRA YANTI, AUZAR SYARIF	¥	
Periodontal Disease and Salivary Pro-Inflammatory Cytokines Level: A Study of Final Trimester Pregnant Women RETNO INDRAWATI ROESTAMADJI, NURAINI INDRASTIE, INDESWATI DIYATRI, UDIJANTO TEDJOSASONGKO, OKI FADHILA, NINUK HARIYANI	¥∘	
Expression of Umami Taste Receptors on Rats (Rattus novergicus) at Different Levels of Food Hardness DEAFITRI PUSPITASARI, IIN INDAH ARIS WATI, HANS LESMANA, TANTIANA, JENNY SUNARIANI	*	
Potential Anti-Degenerative Hypercholesterolemia in Steeping Tea with Combination of Leaves of Pasote (Dysphania Ambrosioides L.), Gedi (Abelmoschus Manihot L.), Tapak Dara (Catharanthus Roseus (L.) G. Don) DINGSE PANDIANGAN, NELSON NAINGGOLAN, MIHAEL VALLERY LOUEIS TUMBOL, CHARLES L KAUNANG, ENDANG PUJIHASTUTI, HENDRA PRATAMA MALIANGKAY	ေ	
Sensory and Physicochemical Characteristics of Cookies Made of Yellow Pitaya (Selenicereusmegalanthus) Peel Flour Caracteristicas Sensoriales Y Fisicoquímicas De Galletas Elaboradas a Partir De Harina De Cáscara De Pitahaya (Selenicereus Megalanthus) AHMED EL SALOUS, ROBERTO ORDOÑEZ-ARAQUE, LUIS ZUÑIGA-MORENO, HUERTA MARCO, JESUS R. MELENDEZ	҂	
Search for More Efficient Payroll Accounting: The Case of The Internatio Pharmaceutical Industry IULIIA ZAUGOLNIKOVA, EKATERINA GOLUBTSOVA, ANNA ZVEREVA	nal	
Modernization of Teaching Methods in Higher Education Taking into Account the Distinctive Features of Modern Students as Representatives of the "Digital Generation" YAKIMOVA TATIANA BORISOVNA, KABANOV OLEG VLADIMIROVICH, CHUMACHENKO ZLATA MIKHAILOVNA, KAZANTSEVA IRINA ANATOLIEVNA, CHARDYMSKIY MAKSIM GEORGIEVICH, SHAMINA SVETLANA VLADIMIROVNA, YUSHCHIK ELENA VLADIMIROVNA, VOLKOV VLADIMIR SERGEEVICH	₩	
Long Term Stability Study of Metronidazole Tablets MAADH T. ABDULRAHMAN, NOOR M. JASIM, SAHAR G. IMRAN	*	
Evaluation of The Effect of Aqueous Extract of Lepidium Sativum Seed on The Adverse Effects of Rat Liver Injury Induced by Sodium Nitrite MAYTHAM ALI KAREEM, ASHWAQ KADHEM OBEID	*	
Comparative Morpho-histological Studies of Tongue Papillae in the pre- pubertal and adult stages of Awassi sheep (Ovis ovis) SINAA JABOURY AL-BAZII, ASHWAQ KADHEM OBEID, RANA MAJEED HAMEED	*	
Association of FTO Gene Polymorphisms (rs9940128 & rs11076023) with Type II Diabetes Mellitus in Obese Iraqi population	×	

LAITH A YOUNUS ARDUL HUSSEIN A ALGENARI MOHAMMED SAFED

Segmentation And Calculation Of Volume Of Tumor On Mri Using Efficient Feature Extraction Techniques NISHA JOSEPH, D MURUGAN, BASIL JOHN THOMAS, RAMYA A The Dynamics of Fatwa among a Diverse Community M.USMAN , MUDOFIR, LAYYIN MAHFIANA, MUH.NASHIRUDIN Simwos: Improving Semantic Similarity Between Gene Ontology Terms Based On Pfam Clans And Pathway Analysis ANOOJA ALI, VISHWANATH R HULIPALLED, S.S.PATIL Study On Impact Of Social Networking Sites On The Performance Of Employees in The Banking Sector.

DR. SARVJEET KAUR CHATRATH, AMANJOT KAUR, HARPREET SINGH Precautionary Measures And The First Wave Evolution Of Covid-19: A Comparison Study A.HAJ ISMAIL, T.JWAID, E.DAWI, A.ABDELKADER Effect Of Butanol Extract Pomegranate Peel (Punica Granatum) Gel As Antioxidant On Shear Bond Strength Of Nanofilled Composite Restoration In Enamel After Bleaching In Office: In Vitro Study SALLY SALSALINA, TRIMURNI ABIDIN, DENNIS Pre and Postnatal Developmental Study of Cornea and lens in Rabbits (Oryctolagus cuniculus) AZHAR SALEEM KHALAF, EKTIFFA S. KHAYOON, ALI FARIS RESHAG Isolation and Amplification of Emm Gene From Streptococcus Pyogenes Isolated from Iraqi Children. NADA ZAIDAN KHALAF, ASRA'A ADNAN ABDUL-JALIL, LAITH MOSLIH Allergic Conjunctivitis and Its Complications Among Patients Attending Al-Nahrain Eye Specialty Center in Ramadi City , THAKIR M. MOHSIN, ZEINA M. ALSABTI, OMAR MUAYAD AL-NAQEEB Microbiological Contaminant Isolation and Detection in Cosmetics Sold in Iraq MUNTAHA A.H.NASIR, QUTAIBA A.QASIM In Silico Identification of Potential Inhibitors Against Sars-Cov-2 Protease X VAJIHEH ESKANDAR Development of The Stable, Reliable, Fast and Simple RP-HPLC Analytical Method for Quantifying Diphenhydramine-Hcl (DPH) In Pharmaceuticals × H.N.K.AL-SALMAN, ERFAN A.S.ALASSADI, RAJAA HUSSEIN FAYADH, HUSSEIN H.HUSSEIN, EKHLAS QANBER JASIM Physiochemical Effects of Nano Particles from Welding Fume on Rumaila Oil Field Welders by Using FESEM- EDS RAFID A.DOOLAB Implementation of Blended Learning Based-Model in English For Specific Purposes for The Islamic University: A Case Of UNISNU, Jepara, Indonesia HARYANTO, PURWANTO, GIYOTO Evaluation Model of Learning in Inclusive Settings for Students with

Disability in INTIS Elementary School Yogyakarta

Reinforcing and Improving the Behavior of Reinforced Concrete Slabs Employing the Optimal Amount of Polymer Fibers and Examining the Effect of The Number of Fiber Layers

SINA BASHIRI, MEHDI KHOSHVATAN **Cultural Based In Peer Education Toward HIV Prevention In Teenagers:** A Case Study Of Teenagers' HIV Risk Behavior In Bukittinggi City OKTAVIANIS, ARNI AMIR, FIRDAWATI, GIWO RUBIYANTO WIYOGO × Staffing Plan for Respiratory Therapists in Saudi Arabia AHMAD ALESSA, Legal Protection Against The Criminalization Of The Notary Profession In . SRI SUHEDININGSIH. SUTEKI. SUKIRNO Strengthening the Asset Recovery Center of the Indonesian Attorney General's Office IMAN KHILMAN, S.H., M.H, DR. INDRA PERWIRA, S.H., M.H (PROMOTOR), APSARI DEWI, S.H., LL.M, PH.D. (CO-PROMOTOR) Analysis Contens Of Natrium Benzoate And Sorbic AcidÍnBeverageSnackSoldAt Sdn Karang Tengah Tangerang City NURHABIBAH , YUSNIDAR YUSUF, MOH. RAMDHAN Activity Analysis Using Biosensor In Machine Learning , DR.P.KANAGARAJU, DR.P.SENTHILRAJA, S.RAJKUMAR, D.SEENIVASAN, R.BASKAR Efficacy Of Shockwave Therapy Versus Intra-Articular Platelet-Rich Plasma Injection In Management Of Knee Osteoarthritis: A Randomized Controlled Trial. MOHAMED HUSSEIN ELGENDY, SARA ABDULLA ELSAMAHY, MOHAMED SERAG ELDEIN MAHGOUB MOSTAFA, MOHAMED SAFWAT KAMAL HAM7A The Role Of Diffusion Weighted Imaging With Background Signal Suppression (Dwibs) In Diagnosis Of Breast Lesions: Comparison With Contrast Enhanced Digital Mammography (Cedm)
FATMA SABER ELSAYED SINGER, SOHA TALAT HAMED, NOHA ABDELSHAFY ELSAID, MARWA ANAS ABDLRAHMAN Long Term Intake Of High Protein Diet Reduces Body Weight And Glucagon Like Peptide-1 (Glp-1) Concentration In Male Wistar Rats AZHAR DZULHADJ B. ARAFAH, ARYADI ARSYAD, AMINUDDIN × AMINIJIDDIN The Inhibition of Food Intake by Peptide YY (PYY) AZHAR DZULHADJ B. ARAFAH, BURHANUDDIN ARAFAH, AZHARIAH NUR B. ARAFAH, FAJRIAH RAHMAH B. ARAFAH Global identities of the local identity-related attitude in the Child Development Centers for protecting educational asylum of early childhoods from rural communities to the schooling cities

JIRAWON TANWATTANA, TOANSAKUL SANTIBOON The Analysis of Proanthocyanidins Cacao Peel Extract (Theobroma cacao L.) Potential on The Expression of TNF-a and COX-2 on Periodontitis Rat YANI CORVIANINDYA RAHAYU, AGUSTIN WULAN SUCI DHARMAYANTI, YOLANDA EKA PUTRI, ANIS IRMAWATI

ALEX YUSRON AL MUFTI, NAHIYAH JAIDI FARAZ, MUKMINAN, ANIS FITRIYAH, SUBAIDI The Reconstruction of Marriage Law in Classic Figh Perspective: The Case of Unregistered Marriage in Indonesia MUNASIR, SA'DULLAH ASSA'IDI Implementation of Digital Curriculum at Madrassa Alivah Balekambang ALI AS'AD, PURWANTO, YUSUF ROHMADI Exploring Marketing Performance Based on Agro Value Co-Creation SAMSUL ARIFIN, ALI, NURUL KOMARIYATIN Same Verses Detection Application: An Innovative Media For Memorizing Qur'an In Tahfidz Pesantren AZZAH NOR LAILA, DARNOTO, ANA RAHMAWATI, HERMAN SURJONO, MUHTADI The Effect of Teacher Motivation and Teacher Work Discipline Towards Costs of Private School Heads in Karanganyar Indonesia SUTARMAN, SUTARNO JOYOATMOJO, NUNUK SURYANI, ASROWI The Information Technology Based-Regional Government Innovation for Integrated Civil Servant Management of East Java Provincial Office NURKHOLIS . SOESILO ZAUHAR. MR.KHAIRUL MULUK. ENDAH SETYOWATI Improving Marketing Performance Through Exploiting Green Product NURUL KOMARYATIN, SAMSUL ARIFIN, ALI **Textile Industrial Liquid Treatment with Activated Carbon** DARSINI AGUS PURWANTO **Empowering Mental Attitude And Mindset Of Business In SMES** Through Sales Tournament For Students Of Sragen School Business, ¥ JOKO SURYONO, MAHENDRA WIJAYA, HERU IRIANTO, MOHAMAD HARISUDIN **Exploring the Implementation of Human Resources Management for** SITI ROMLAH, HARYANTO, MUNASIR The Student Perceptions on The Online English Teaching in Pandemic Era: Voice from UNISNU Jepara, Indonesia , DWI ERLIN EFFENDI Giving Students Freedom to Learn Through the Implementation of Lesson HERRY AGUS SUSANTO MEIDAWATI SUSWANDARI DEWI KUSUMANINGSIH, SRI MULYATI Effect of Some Bioactive Flavonoids on Lysosomal QUTAIBA A. QASIM Role of Flavonoid Rich Fraction of Butea monosperma Linn. In Memory Enhancing Activity
GHASSAN SALAH AHMED, MAZIN A.A.NAJM , AHMED S.ABDUL JABBAR,
FALAH HASSAN SHARI

Spectral and Thermodynamic Study of Amoxicillin Drug with Surfactant SLS In Presence of Silver Nanoparticles LIQAA HUSSEIN ALWAN, HIND AHMED MAHMOUD Efficacy of biological agents in stricturing Crohn's disease: A retrospective cohort study
MAHMOUD ALCHLAIHAWI, SRIHARAN SELVARATNAM, SUDARSHAN × PARAMSOTHY, RUPERT LEONG Analytical study of fixation failure in adult limb fracture: Prospective study in single center institution , MUSTAFA WALEED YAHYA Dental fear and their effect on their behaviour during the dental treatment among children. KIRTANA GOPALASAMY, DEEPA GURUNATHAN, A.C.KANTHASWAMY, DR. VEERALE PANCHAL, DR.LAKSHMI.T Synthesis Of Phytofunctionalize Zinc-Oxide Nanoparticles From Acacia KIRUTHIKA PATTURAJA, DR.LAKSHMI.T Efficacy of Commercially Available Oral Antimicrobial and Topical Anesthetic Gels against Streptococcus mutans
SHABANA BOWSIYA, DEEPA GURUNATHAN, MADHU SUDHAN VASANTHARAJAN, MURALIDHARAN, DR.LAKSHMI.T Assessment of Oxidative stress and Antioxidant Level in Oral Submucous VAISHNAVI SIVAKALI SUBRAMANIAN, ROY ANITHA . T.LAKSHMI Effect of Green Tea (Camellia Sinensis) Extract Administration on Sperm Quality of Mice (Mus Musculus) Exposed To 2,3,7,8-Tetrachlorodibenzo-P-Dioxin , MEY VANDA PUSPARINA SAJIDA, EPY MUHAMMAD LUQMAN, INDAH NORMA TRIANA, WIDJIATI WIDJIATI The Effect of Carbofuran Exposure on Mice During Lactation Period Against on Histopathology Description of The Heart of Mice (Mus Musculus) Offspring
AISYAH ASRIANTI1, WIDJIATI, DJOKO LEGOWO, LILIK MASLACHAH, ARIMBI, EPY MUHAMMAD LUQMAN Antibacterial And Antifungal Activity Of A Plant Substance Of The Genus

AISYAH ĀSRIANT11, WIDJIATI, DJOKO LEGOWO, LILIK MASLACHAH, ARIME EPY MUHAMMAD LUQMAN

Antibacterial And Antifungal Activity Of A Plant Substance Of The Genus Calligonum

BAIDUYSENOVA ALIYA UTESHOVNA, BEKENOVA AYNUR ORDABAEVNA, BEKNIYAZOVA GULIMSHAT ALPYSBAEVNA, SUTIMBEKOVA NAZGUL SEITBEKOVNA, DUISEBEKOVA GULBANU PRALYEVNA

Induction of Collagen Formation Through the Utilize of Microneedle in the Treatment of Various Types of Scars in Aesthetic Medicine Field AHMAD AB YOSEF KINANI

Assessment of sheep ova viability and morphology vitrified using new cryoprotectant solutions

MSC. MUDHAFAR ABDULHUSSEIN M, PROF. DR. MUHAMMAD-BAQIR M-R.FAKHRILDIN, MSC. AHMED HUSSEIN

Diagnostic Accuracy of Proclacitonin Compared to C-Reactive Protien in Recognizing Bacteremia Determined by Blood Culture KHALID KHALIL ALAARAJI, RIADH A.HENWA, DHUFFER SHEHAB QASIM

DR HEMANT D TOSHIKHANE. DR SHAILESH V DESHPANDE. DR HARISH DAGA Avurvedic Management of Vicharchika - Single Case Study DR HARISH DAGA, DR HEMANT TOSHIKHANE, DR KIRAN THAKUR, DR VAIDEHI RAOLE Management of Renal Calculus- Single Case Study , DR.HARISH DAGA, DR HEMANT TOSHIKHANE, DR.RUSHIKESH KANGAD, DR.OMPRAKASH DAVE The Effect of Problem Solving Therapy on Reducing Negative Emotions in Elderly with Prolonged Grief Disorder (PGD)

HAMID ZOLFAGHARI, MOHAMMAD EBRAHIM HOKMABADI, FARZANEH KHODABANDEH, MAHDI KARIMI, MAHMOOD BEHNAMINIA, AREFEH ALISHAH SARS-Cov-2 Genomic Variations Among Isolates from Jordanian **Patients** WAJDY J.AL-AWAIDA, HAMZEH J. AL-AMEER, MOHAMED SAMY ABOUSENNA, REFAT NIMER, HAYAT O. AL-ASASFEH, SEVERIN ALEXANDER EVGENIEVICH. YAKUNINA ELENA BORISOVNA. BAKAEVA ZARINA VAGICAINE, OMAR AL BAWAREED, BAKER JAWABRAH AL-HOURANI, NAJAH R. HADI Cystatin C Assessment In Pediatric ?-Thalassemia Major And Intermedia: A Marker Of Subclinical Cardiovascular Dysfunction X MOHAMED BESHIR, DIANA HANNA, NAGLAA KHALIFA, AHMED **ELHEWALA** An Effective Cascaded Approach for EEG Artifacts Elimination , DR.SANTOSH KUMAR VISHWAKARMA, DR.PRAKASH CHANDRA SHARMA, DR.ROHIT RAJA, DR.VANDANA ROY, SAKSHI TOMAR Detection of sleep apnea through heart rate signal using Convolutional Neural Network , DR.SANTOSH KUMAR VISHWAKARMA, DR.SAURABH SINGH VERMA, MR.RAJIT NAIR, DR.VANDANA ROY4, AYUSHI AGRAWAL A Pilot Survey Study of Menstrual Cycle Inapparantly Healthy Females of Different Body Mass Index , DR MANJEET KAUR, DR NEHA GADGIL Application Of Dixon Test For Rejection Of Outliers In Calibration Curve
.ALANKAR SHRIVASTAVA. ABHISHEK SHARMA. DEEPAK GUPTA A Renal Calculus Non-Surgical Ayurvedic Treatment – A Case Study , DR CHANDRABHAN SINGH GURJAR, DR HEMANT D TOSHIKHANE, DR 🛠 Effect of Glycyrrhiza Glabra as Motility Stimulant on Sperm Function for Patients with Varicocele and Diabetes Before and After In-Vitro Preparation for ICSI ETHMAN HASHEM MOHAMMED, DR.AMOURA M.ABU-EL-NAGA, DR. SAAD SALIH ALDUJAILY Formulation and Characterization of Tyrosine Kinase Inhibitor Loaded NLCs: Application of 23 Full Factorial Design Approach DHAIRYSHEEL GHADGE, NAMDEO JADHAV Histopathological spectrum of benign and malignant lesions of oral cavity in a patient attending Coastal tertiary care hospital – A × Retrospective study

INAAM MAHMOOD ALRUBAYAE, KADHIM FADHIL KADHIM Managers' Strategic Directions To The Downtrend: A Case Of Selected Gulf-Kazakhstan Oil And Gas Industry
ROMMEL P. SERGIO, PHD, MARIA JADE CATALAN-OPULENCIA, PHD, AKINOLA O.FADAHUNSI, PHD Factors Influencing Smart City Development in Khon Kaen, Thailand AWUTH RUENPAKPOJ, SUKANYA AIM-IM-THAM, SUTTIPONG HOXSUWAN, NORRAPAT NOILUBLAO, PONGSATEAN LUENGALONGKOT, CHULA CHARERNVONG, DOMTHARADOL ANANTASAN, SUPHATTHANI KHOONSINGSAKUN, SUCHIN CHARNSUNGNERN, AKKAKORN CHAIYAPONG, KORAKOD TONGKACHOK, THONGPHON PROMSAKA NA SAKOLNAKORN Factors Associated With Gait, Balance And Strength Abnormalities Among Indonesian Elderly
INDRI HAPSARI SUSILOWATI, SUSIANA NUGRAHA, SABARINAH, BONARDO PRAYOGO HASIHOLAN, SUPA PENGPID, KARL PELTZER The Influence Of Disputants Perceptions On The Process And Outcome Of Negotiation
DAN-MALLAM YAKUBU ABIGAIL, DULZALANI BIN EDEN, SITI FATEHA BINTI DOLHADI, ALIYU MUSTAPHA IDOWU The Influence Of Disputants Perceptions On The Process And Outcome Of Negotiation
DAN-MALLAM YAKUBU ABIGAIL, DULZALANI BIN EDEN, SITI FATEHA BINTI DOLHADI, ALIYU MUSTAPHA IDOWU Organizational development: Problems, Challenges, and Characteristics of THONGPHON PROMSAKA NA SAKOLNAKORN. WANCHAIDHAMMASACCAKARN, SUTTIPONG HOXSUWAN, PONGSATEAN LUENGALONGKOT, CHULA CHARERNVONG, SUCHIN CHANSUNGNERN, CHUMPOL SUWICHIAN, DENNARONG THAMMA, KORAKOD TONGKACHOK Exploring The Students' Anger Control In Al-Qur'an And The Psychology Of Islamic Education(A Case Study On Private Higher Education Students At MUFID . SISWANTO MASRURI. MUHAMMAD AZHAR Evaluation of Antioxidant and Anti-inflammatory activities of Periploca aphylla NEELAM SHERWANI, SARDAR A. FAROOQ, KHALID AL MAQBALI Effectiveness of Mindfulness Meditation Program on Perceived Stress Reduction among New University StudentsBy
MOHAMMAD BANI YOUNIS, RN, PHD, AHMAD B.AL-RAWASHDEH, RN, PHD,
YOUSEF RUBBAI, RN, MSN, AHMAD M. AL-SAYEH - RN, MSN, AHLAM JARADAT - RN. MSN Returning Migrant Worker: Issues And Protection During The Covid-19 Pandemic In Indonesia DEDE YUSUF MACAN EFFENDI, ASEP SUMARYANA, ARI BAINUS, RAMADHAN PANCASILAWAN Effect of Ayurvedic Management in Covid-19 Pneumonia: A Series of . PRASANTHI CHERUKURI. VASUNDARA GARDAS . PENTAKOTA KIRANMAYI

Mycodiesel Production from some Isolates of Oleaginous Fungi Isolated

from Oil-Rich Soils in Basrah

Differences of Social Sciences Learning Results Using Creative Problem Solving Learning Model Using Prob-lem Based Learning Learning Model(Survey of Public Elementary School Students in X Bengkulu City)
SUHIRMAN , NURLAILI, NELSON, AHMAD SYARIFIN, WIWINDA The Effect of Emotional Intelligence and Learning Motivation on Student Achievement Levels(Survey in Junior High School Students in Bengkulu Province Years 2019)
SUHIRMAN, NURLAILI, ZULKARNAIN S, MUHAMMAD TAQIYUDDIN, AHMAD SYARIFIN Exploitation of Macro-bend Induced Loss Mechanism in the Design and Construction of an Optical Fiber Glass Refractometer Operating at Multiple Wavelengths
S.SRINIVASULU, DR.S.VENKATESWARARAO Role of Colon Transit Study in Refractory Constipation PENTAKOTA KIRANMAYI, YELLAPU RADHA KRISHNA, PRASANTHI × CHERUKURI, SUMERA SALOMI SOUDAGAR Methanolysis and Hydrolysis Studies of Bimetallic Systems: Ba{Ti (OPri)6, and Ba{Ti2 (OPri)9}2 , SARASWATI KUMARI OLA, VEENA DHAYAL, JAYA RAI Evaluation of Hepatoprotective activity of Ochna obtusata extract on Paracetamol induced Hepatotoxicity in Rats RAVI KUMAR VAKKALAGADDA, SRINIVAS LANKALAPALLI ¥ Study the Effect of Non-Pharmaceutical Approach on Traumatic Nipple for Lactating Mothers
RANDA MOHAMED ABOBAKER, HAJIR A. AL-SAIHATI, MERVAT AMIN SAYED, ABDULRAHMAN AHMAD ALNAIM, SAFIA BELAL, DOAA M. ELIAN Antioxidant, anti-tyrosinase, anti-elastase and cytotoxicity of ethanol extract from Cnidoscolus chayamansa (Mc Vaugh) leaf extract KANITTADA THONGKAO, NARIN KAKATUM, PIMPORN THONGMUANG, YUTTANA SUDJAROEN The relationship of bone mineral density (BMD), age and body mass index (BMI) among postmenopausal women, Samut Songkhram, Thailand YUTTANA SUDJAROEN, PIMPORN THONGMUANG Whey protein Supplements intake and Their Contribution to fat substrates metabolism and body compositions Among Young females Subjects MANAR M BADAWY, Q.I.MUAIDI, AMEL ELABDDEL KARIM, NESMA M ALLAM In vitro anti-inflammatory and anti-microbial activities of ethanol extract from Cnidoscolus chayamansa (Mc Vaugh) leaves KANITTADA THONGKAO, NARIN KAKATUM, PIMPORN THONGMUANG, YUTTANA SUDJAROEN Impact of Maternal Hypothyroidism on Pituitary-Ovarian –Axis Activity in Females Offspring at Puberty SARAH JAAFAR SAADOON, JASSIM M.A.ALKALBY Study Of Teratogenic Effects Of Chinese Spinach Extract (Amaranthus

Tricolor L) In Wistar Rat

DEWI DAMAYANTI ABDUL KARIM , SITI ROHANI, PSIARI KUSUMA WARDANI, RAFI NUR FAIZI AKBAR, REDI ARIF MUZANI, VEVI INDRIANI, SALMA ADILA, NUR AMINUDIN

The Correlation Between the Use of Hormonal Contraception to the Accomplishment of Exclusive Breastfeeding EVA YUNITASARI, ANGGI KUSUMA, SITI MAESAROH, GRASIANA FLORIDA BOA, DIAN NUR ADKHANA SARI

The Impact of Corona Virus (Covid-19) on Decision Making of Healthy Living Communities with Social Environments and Motivation as Intervening

SITTI RIZKI MULYANI, VIVI NILA SARI, MARTA WIDIAN SARI, HAPZI ALI

Drug Utilization Evaluation of Antibiotics Used in Orthopaedics Department in A Tertiary Care Hospital of Pathanamthitta District, Kerala , PHILIP JACOB, ARUL BALASUBRAMANIAN, KOTHAÍ RAMALINGAM

Quality by Design Based Approach for the Estimation of Telmisartan in Presence of Related Substances by RP-HPLC Method SACHIN GHOLVE, MOHAMMAD IMRAN ANEES, MARIA SAIFEE, JAIPRAKASH SANGSHETTI, OMPRAKASH BHUSNURE, ABUBAKAR SALAM BAWAZIR

Development and Validation of RP-HPLC Method for Estimation of Etoposide in Liposomes
A.R.FUGATE, S.N.NAGOBA, S.R.HYAM

Design, Formulation and Evaluation of Cabozantinib Loaded Liposome by RP-HPLC

K.B.BHANSALI, S.N.NAGOBA, S.R.HYAM

An observational study on prescribing pattern and effect of medication 2 diabetes adherence on clinical outcomes in type SOURABH KOSEY, SAURABH SHARMA

Formulation And Evaluation Of Herbal Nanoparticles Prepared From **Extracts Of Antidiabetic Medicinal Plants**. MOHOLKAR APARARK V, JADGE DHANRAJ R, NAGOBA SHIVAPPA N

Design of Experiment Approach in Development of Hydrophilic Matrix Tablet of Venlafaxine HCI: In vitro and In vivo studies
MARIA SAIFEE, V.U.RAO, S.D.BARHATE

Bioanaltical Method Development And Validation Of Primidone In Rat Plasma By K3edta Using Lc-Ms/Ms KHEDKAR NAVNATH, S. SATHESH KUMAR

Potential Of Indian Pharmaceutical Market In African Countries CHAMNGEI SICHEI CHEWOREI, DR HAREESH DARA, JAI KUMAR MISHRA

Formulation And Evalution of Cefixime by Liposomal Technique AZRA UNNISA, DR.A.MADHUKAR

Novel Extraction solvent Assisted Identification and Quantification of Caffeine in Different multiple Beverages by using Gas Chromatography

Mass Spectrometry B.V. NARASIMHA RAJU KATARI, VEMULA MADHU, RAGHU BABU KORUPOLU, ANNAPURNA NOWDURI, MURALIDHARAN KALIYAPERUMAL, CHIDANANDA SWAMY RUMALLA

Method Development And Validation For Metal Analysis Of Herbal Drug (Saraswatarishta) Using Inductive Coupled Plasma Optical Emission Spectroscopy SRIDHAR BABU GUMMADI, SNIGDHA DAMIREDDY

Validated Method Development For The Simultaneous Estimation Of Empagliflozin, Linagliptin, And Metformin In Marketed Formulation Using Uv Vis Spectrophotometer SHRIKRISHNA BAOKAR, RAJENDRA PATIL, ADITYA NATH PANDEY

Total Phenolic Content, Flavonoid Content And Antioxidant Potential Of

Leaves And Stems Of Dioscorea Floribunda ATUL SHANKARRAO BHUJBAL, RAJENDRA PATIL, ADITYA NATH PANDEY

Simultaneous spectrophotometric evaluation in pharmaceutical dosage type of trimethoprim and albendazole.
KHUSHBOO GUPTA

×

Immunomodulatory effects of potent bioactive compounds derived from plants NIRALI BUDHBHATTI, DILENDRA CHANDRAKER

Lichen as potential armamentarium against the SARS CoV-2 (COVID-19) DEVVRET VERMA, HIMANSHU RAI , SUGAM GUPTA, RAKESH SRIVASTA KUMUD PANT, RAJAN K GUPTA, BHASKER PANT, ASHISH THAPLIYAL, SHREESH GUPTA, D.K.UPRETI

Design, Synthesis And Biological Evaluation Of Some Azole Derivatives SWEETI ASHOK SHEWALE, P.J.SHIROTE, NEETA VASANT WADD

Identification Of Quercetin Of Rhizomes Of Kaempferia Galangal, Kaempferia Parviflora And Kaempferia Pulchra By Hplc SUBHASH CHANDRA MISHRA, NEERAJ SHARMA

Hplc Method Development And Validation For The Estimation Of Deflazacort In Nanosponges Formulations SARVESH MISHRA, NEERAJ SHARMA AND SHAILESH JAIN

The Anti-Tubercular Activity Assessment Of Extracts Of Medicinal Plants; Traditionally Used By Tribes Of India , DHARMENDRA KUMAR KUSHWAHA, RAJSHREE PANDEY, RAVISHANKAR

Formulation and In-vitro Evaluation of Floating Drug Delivery System for

, D.VIJAY KUMAR, RAKESH KUMAR JAT, GAMPA VIJAY KUMAR

Analytical Method Development And Validation Of Perindopril In Bio Relevant Dissolution Medium Using Rp-Hplc MERUGU MADHUSUDHAN, DR.RAKESH KUMAR JAT, DR.GAMPA VIJAY KUMAR

The Impact of Myocardial Infarction in Hypertension and Diabetes Mellitus Patients with Other Risk Factors

RAVI CHANDER THATIPELLI, SHIREESHA BUSSARI, HAREESH DARA

3D Modeling and Static Analysis of Telescopic Shock Absorber Unit MOPATI SOMA SUNDARA VENKATA HANUMAN, T.SESHAIAH, L.VENKATESHWARALU, V.S.J.C.PRASAD

Design and Development of nanoparticle based antidiabetic formulation of Aegle marmelos Plant
MRUNAL K. SHIRSAT, VAIBHAV C. SHILIMKAR

A Promising Challenges In Sublingual Drug Delivery System VIKRANT NIKAM, GAURI SHAHARKAR, VIVEKANAND KASHID, POOJA CHAVAN, JYOTI KHAPARE

The Promising Potential Plants Metabolites For Neurodegenerative Diseases SHAIK ABDUL SALEEM, R.KOTHAI, B.ARUL

Analytical Method Development And Validation For Estimation Of Bilastine In Pharmaceutical Formulationby Reverse Phase High Performance Liquid Chromatography SRINIVAS AMPATI

Neurosurgical Treatment-Drug - Drug Interactions GILLELLA PRANEETH, SRIDHAR BABU GUMMADI

Neuroprotective And Anti-Alzheimer's Effects Of Plant- Zaga Latifolia MADHUSUDAN REDDY, HARIKIRAN LINGABATHULA, RAKESH KUMAR JAT

Design, Development And Characterization Of Nano-Emulsion Based Nicardipine Hydrochloride Gel 20mg G.GOPI, B.KUMAR, K.B.CHANDRA SEKHAR

Bioanalytical Method Development And Validation Of Cabozantinib In Rat Plasma By Using Lc-Ms/Ms SHAILAJA KONA, GANDLA KUMARASWAMY

Formulation And Development Of Quetiapine Mouth Dissolving Films Using

Doe Approach MEGHA AGRAWAL, SHAH DHIREN F

Evaluation Of Antidiabetic And Antilipidemic Activities Of Euphorbia Caducifolia Latex Powder In Alloxan-Induced Diabetic Rats KRISHNAVENI BOMMINENI, MADHUSUDHAN RAO YAMSANI

Challenges of Artificial Intelligence in Controlling COVID-19 DR.SATYAM PRAKASH SRIVASTAVA, DR.RUPA KHANNA MALHOTRA

Mental health of teachers in private higher educational institutes of Uttarakahnd: an empirical analysis
AMIT KUMAR UNIYAL, RUPA KHANNA, POOJA KANOJIA

Tissue culture of Dendrobium orchids and its application in capacity building in Uttarakhand MANU PANT, HIMANSHU BADONI

An Overview of COVID-19 Pandemic along with Historical Epidemic, Black Death: Their Impact on the Environment SIDDHARTH GOSWAMI, AMIT GUPTA

Parkinson's Disease: An Introduction to the Causes and Management Strategies ASHFAQ AHMAD SHAH, KHUSHI KASHYAP, AMIT GUPTA

Influence of Emerging Contaminants on human health and water resources RAKESH PANT, NIRMAL PATRICK, AMIT GUPTA

Qualification of Metabolites in the Conditioned Medium of MSCs Cultured Using FBS and Platelet Lysate-A Comparative Analysis L.PRAVEEN KUMAR, MAINAK DUTTA, SANGEETHA KANDOI, SAN GUPTA, P.RAGHU BABU, ANGELINE JULIUS, REMYA PRAVEEN, SANTOSH 🧩 K.RAJAGOPAL, DR.S.VIJAYALAKSHMI

Effect of BAP on in vitro propagation of Taxus contorta – an endangered multipurpose tree of the Western Himalayas
SUSHANT SHARMA, YASHASWI SINGH, MAHIMA, AMBIKA, SEEMA SINGH, AJAY THAKUR

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Research Article

Procalcitonin, IL-1β, HSP10 and Resolvin D2 Mechanism as Sepsis Biomarkers in Sepsis Model

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ABSTRACT

Background: The use of various biomarkers in sepsis has an important role in helping diagnosis and decision making therapy quickly and accurately. This study aimed to explain the mechanism of procalcitonin, IL-Iβ, RAMPs markers such as HSP10 and resolvin D2 as biomarkers of sepsis in the sepsis model of *Eschericia coli* infection given with meropenem antibiotics.

Methods: An experimental study using the *E. coli* sepsis model in male *Rattus norvegicus* was conducted in 2 stages. The first step was to observe a model of sepsis in rats and determine the time of sepsis and the second step was to compare levels of procalcitonin, HSP10, IL-1 β , and resolvin D2 with different dosage of germs and different antibiotic time of administration.

Results: The time of sepsis was occurred between 8 and 10 hours. There were differences in *E. coli* exposure with IL-1 β levels (p = 0.03), procalcitonin (p = 0.084), HSP10 (p = 0.000), and resolvin D2 (p = 0.024). There were differences in levels of procalcitonin and resolvin D2 between groups at 24, 48 and 72 hours and between the treatment of antibiotics at different times and without antibiotic administration. While there were differences the levels of IL-1 β and HSP10 between groups at 24 and 72 hours, but there was no difference at 48 hours antibiotic treatments.

Conclusion: Resolvin D2 and HSP10 have a slightly different pattern at 24 and 72 hours compared to procalcitonin and HSP10. Thus, it has the potential to be developed as a new biomarker in sepsis.

Keywords: sepsis, biomarker, Procalcitonin, IL-1β, HSP10, Resolvin D2

INTRODUCTION

Sepsis is a systemic inflammatory disease with a high risk of mortality. Sepsis is still big problem and needs to improve the management [1]. Excessive uncontrolled inflammation and an inappropriate immune response are special characteristics that make it difficult to identify good targets for treatment and treatment. Delayed diagnosis and initiation of antibiotic therapy have been reported to increase mortality [2, 3]. The use of various biomarkers in sepsis has an important role in helping diagnosis and decision making therapy quickly and accurately [4, 5]. One marker that has been recognized for the diagnosis and prognosis of sepsis is procalcitonin. In addition, procalcitonin can also be used as a guide to continue or stop antibiotic therapy [6-8]. Although various efforts through the management of sepsis and biomarker research have been developed to reduce mortality,

sepsis mortality is still high, sepsis by 30%, severe sepsis by 50%, and septic shock by 80% [9].

Procalcitonin is a biomarker that has been extensively studied for early diagnosis of sepsis and is superior to CRP and IL-6 [10]. In bacterial sepsis, procalcitonin produced various is by neuroendocrine cells, and the main site of production is in the liver. Procalcitonin is induced directly by LPS and or indirectly by proinflammatory cytokines such as IL-1b, IL-2, IL-6, and $TNF\alpha$ [11–13]. The kinetic profile of procalcitonin is better than CRP because it starts to increase 3-4 hours after the onset of systemic infection and reaches a peak between 8 to 24 hours. The role of procalcitonin in sepsis is still not fully known, but it is known that the presence of inflammation trigger the release will procalcitonin through two processes, either directly or indirectly. Toxins and LPS will directly trigger procalcitonin release. and various proinflammatory cytokines such as IL-1 β , IL-6, and TNF α indirectly affect procalcitonin production [14]. In addition, other studies states that procalcitonin have good accuracy to predict bacterimia and fungal bloodstream infection [15].

Endogenous mediators known as DAMPs (danger associated molecular patterns), for example, are HSP (heat shock protein), fibrinogen and HMGB-1 (high mobility group box-1 protein). DAMPs and PAMPs activate inflammation, followed by activation of Caspase-1, the release of cytokines IL-1ß and ILand the occurrence of Pyroptosis. Inflammasome is a multiprotein complex in mononuclear phagocyte cytosols, dendritic cells and other cell types proteolytically producing the active form IL-1ß from the pro-inactive precursor IL-1B. The formation of inflammatory complexes includes NLRP3 (a NOD like pattern receptor receptor), a protein adapter, and the enzyme caspase-1, stimulated by microbial products, cell damage-associated molecules and crystals [16]. HSP27, HSP10, and α -crystallin are included in RAMPs as regulators and resolution of acute inflammation [17]. Resolvin D2 in studies in rats leukocyte infiltration, reduces inflammatory cytokines, and bacteria. Minimizing inflammation might slow resolution because of inappropriate induction of anti-inflammatory and pro-resolving pathways. Some new mediators do not simply or easily reduce inflammation but contribute to the exact time of resolution [18].

Preclinical studies provide real hope for the therapeutic aspects of sepsis; among them are sepsis models in rats that have similar mediators and molecular variations in sepsis patients. Studies in mouse models compared to other animals have many advantages, especially the problem of deep mechanisms that are difficult for us to understand in humans because of ethical issues. So that further evaluation of research on the model is needed to be applied to humans. Animal models used in the study of sepsis are non surgical models, surgical, implantation, toxaemia, live bacteria models, cecal ligation puncture (CLP), and colon ascendent stent peritonitis (CASP) [19]. This study aimed to explain the mechanism of procalcitonin markers, IL-1B markers, RAMPs markers, such as HSP10, and resolvin D2 as biomarkers of sepsis in the sepsis model of E. coli infection given meropenem antibiotics.

METHODS

This was an experimental study using the *E. coli* sepsis model in male rats (*Rattus norvegicus*) wistar strains. The study was conducted in 2 stages. The

first step was to look for a model of sepsis in rats and determine the time of sepsis. Male rats were divided into 2 groups, carried out randomly to get treatment as the sepsis model group was given with E. coli 0.5 mc Farland 0.1 ml, and the control group was given with NaCl 0.9% 0.1 ml intravenously and evaluated every 2 hours to take IL-1 β and TNF α levels by ELISA, measured temperature increases, and complete blood levels. Descriptive analysis of IL-1 β and TNF α was to determine the time of occurrence of known sepsis from levels increasing from normal to 2 times the SD (standard deviation), increasing in leukocyte levels >10.5 x $10^3/\mu$ l, and increasing in rectal temperature >38.5°C.

Thus, the second step was to calculate and compare levels of procalcitonin, HSP10, IL-1B and resolvin D2 with different dosage of germs and different antibiotic time. Adult male Rattus norvegicus Wistar strain with 190-200 grams body weight which met the inclusion criteria included in this study. Male rats were divided into 6 groups. Group 1 was sepsis group with E. coli 0.5 mc Farland 0,1 ml, and Group 2 was sepsis group with E. coli 1 mc Farland 0,1 ml. Group 3 was control group given by NaCl 3% 0.1 ml. Group 4 was sepsis model group with E. coli 0.5 mc Farland which given by meropenem antibiotic at hour-2. Group 5 was sepsis model group with E. coli 0.5 mc Farland given by meropenem antibiotic at hour-10, and group 6 was sepsis model group with E. coli 0.5 mc Farland given by meropenem antibiotic at hour-22. Blood sampling was taken and evaluated at 24, 48, and 72 hours after administration of E. coli. Procalcitonin, IL1-β, HSP10, and resolvin D2 were examined by the ELISA.

The statistical test was done in stages: the normality test was used Shapiro Wilk when data were normally distributed. To observe the differences between groups, we used ANOVA or Kruskal Wallis or Mann Whitney. The study was conducted in the Animal Laboratory of the Faculty of Veterinary Medicine. Universitas Airlangga, Surabaya, Indonesia. The examination of IL-1 β , TNF α , procalcitonin, HSP10 and resolvin D2 was conducted at the Biology Services Unit of Faculty of Science and Technology and Institute of Tropical Universitas Surabaya, Disease, Airlangga, Indonesia.

RESULTS

Determining Sepsis Time by Using Temperature, Complete Blood Markers, TNFα, IL1-□TNFα

This study determined the time of sepsis using TNF α , and IL1- β . We evaluated every 2 hours in 24 hours.

This sample study was *Rattus novergicus* Wistar strain with mean weight 170.55 grams. This study obtained the time of sepsis between 8 and 10 hours

where the increased level of temperature increased of leukocytes. Animals began to be lazy to move and did not want to eat. When IL-1 β was used, these events increased 2 times. While using TNF α , there has been an increase of 2 times at the 2nd hour, but the temperature has not been followed (Table 1).

Table 1: The IL-1 β level, TNF α level, temperature in first stage of study

Mean	IL-1β	Hour	Mean	Mean TNFα ng/L	Mean leuco	cyte
pg/mL			temperature °C		$10^{3}/\mu$ l	
277.50		0	36.2	464.514	8.3	
328.17		2	36.5	774.190	13.9	
346.23		4	37.1	637.466	15.6	
491.28		6	37.7	470.241	13.8	
512.45		8	38.7	395.409	14.9	
544.46		10	38.5	437.363	23.4	
932.99		12	38.8	693.453	21.3	
1201.91		24	38.0	548.052	20.5	

Calculating and Comparing the Levels of IL-1 β , procalcitonin, HSP10, and Resolvin D2 with Different Dosages of Germs and Different Times of Antibiotic

This study found that there were differences in *E. coli* exposure with IL-1 β levels (p = 0.03), procalcitonin (p = 0.084), HSP10 (p = 0,000), and resolvin D2 (p = 0.024). There were differences in levels of procalcitonin and resolvin D2 between

groups at 24, 48, and 72 hours between the treatment of antibiotics at different times and without antibiotic administration. Meanwhile, there were differences the levels of IL-1 β and HSP10 between groups at 24 and 72 hours, but there was no difference at 48 hours between the different antibiotic treatments and without antibiotics (**Table 2**).

Table 2: IL-1β, Procalcitonin, HSP10, and Resolvin D2 Levels

Variable	Mean	Standard Deviation	Median	Minimum	Maximum
IL-1β					
Hour 24	1167.17	765.31	769.96	390.17	3003.51
Hour 48	1791.61	700.44	1464.56	354.01	3079.06
Hour 72	1246.85	640.62	1373.38	216.56	2173.87
Procalcitonin					
Hour 24	880.95	490.80	724.79	351.84	2195.76
Hour 48	1175.61	366.31	1144.90	360.37	2136.00
Hour 72	893.86	659.84	718.40	187.88	2026.63
HSP10					
Hour 24	14.83	7.94	7.83	3.02	31.29
Hour 48	14.49	7.85	13.74	3.09	35.39
Hour 72	10.61	8.24	9.12	1.10	36.07
Resolvin D2					
Hour 24	1669.93	161.49	1658.65	1916.74	1327.74
Hour 48	1587.24	107.33	1574.82	1812.40	1361.71
Hour 72	1649.77	115.84	1670.39	1885.83	1391.71

Analyzing the Relationship of II-1 β , Procalcitonin, HSP10 and Resolvin D2 Levels in the Sepsis Model with Different Doses and Timing of Meropenam Antibiotic Administration

After seeing the results of the biomarker statistical test, the researchers wanted to see the dynamics of each treatment group in the development of the four biomarkers in the 24th, 48th and 72th hour evaluation. In the 24-hour analysis, the most significant difference in resolvin D2 levels was in the low-dose E. coli exposure group without antibiotics and the sepsis group given antibiotics at the 10th hour (p = 0.000). The next most significant difference was procalcitonin levels in the low-dose coli group without antibiotics and the administration of antibiotics at the 10th hour (p = 0.022). In the 48th hour analysis, there was the most significant difference in procalcitonin levels in the low-dose E. coli group without antibiotics and the low-dose E. coli group given with antibiotics at the 22nd hour (p = 0.04). Then, there were differences in resolvin D2 levels in the low-dose E. coli exposure group without antibiotics and the sepsis group with low-dose E. coli given with antibiotics at the 10th hour (p = 0.003). In the 72hour analysis, the most significant difference was resolvin D2 levels between the sepsis group exposed to low-dose E. coli without antibiotics and the sepsis group given with antibiotics at the 22nd hour (p = 0.000). Then, there were differences in resolvin D2 levels between the sepsis group given with a low dose of E. coli and antibiotics at the 10th hour and the antibiotic group at the 22nd hour (p = 0,000). In addition, HSP10 levels were also the most significant difference in the low-dose E. coli group without antibiotics and the E. coli group given with antibiotics at the 22nd hour (p = 0.027). Procalcitonin levels also showed a significant difference between groups at the 72nd hour between low-dose E. coli without antibiotics and low-dose E. coli with antibiotics at the 10th hour (p = 0.000).

DISCUSSION

The results of the study showed that there were differences in the levels of procalcitonin and resolvin D2 between groups at 24, 48 and 72 hours between the different antibiotic treatments and without antibiotics. Meanwhile, at IL-1 β and HSP10 levels, there were differences between groups at 24 and 72 hours, but there was no difference at 48 hours between the different antibiotic treatments and without antibiotics. Procalcitonin is a marker used as a guide to start and stop anatibiotics in sepsis, having a similar

pattern in all groups with IL-1β. Resolvin D2 and HSP10 have a slightly different pattern at 24 and 72 hours compared to procalcitonin and HSP10. In sepsis, bacteria show that the gene 1 calcitonin mRNA is organized more neatly than other inflammatory markers such as the TNFα gene, IL-1β, whereas mature calcitonin does not increase during sepsis, but the discovery of procalcitonin as part of increased calcitonin is expected to be a critical marker of cases [11]. This study supports the previous research that resolvin D2 is a lipid mediator stimulating macrophages via alternative pathways to stimulate T cells to activate the anti-inflammatory pathway [18].

The sepsis model in rats given antibiotic meropenam was carried out using E. coli isolate ATCC 25922 with a dose of 0.5 mc Farland (equivalent 1.5x10⁸/ml) intravenously 0.1 ml compared with NaCl 0.9%. A literature mentions the making of an intravenous sepsis model using E. coli doses of 4-5x108 [20]. Some researchers have criteria according to the facilities they have and by calculating cytokine levels. Bone criteria from sepsis use parameters, temperature, pulse, breath count, leukocytes. Meanwhile, SSC provides guidelines for increasing procalcitonin 2SD [6]. We set an estimated 8 hours; as for the basis used by researchers is to use temperatures above 38.5°C, the number of leukocytes above $10.5x10^3/\mu l$ and increasing levels of TNFα, and IL-1β 2 times above normal. TNFα The clinical signs of experimental animals observed to determine sepsis piloererection, hyperpnea and decreased motor activity in the first 6 hours [21]. In this study, there were also the same signs in the first 6 hours. Leukocyte levels have increased starting at 2 hours, while the new temperature increased at 6 hours, and IL-1ß increased 2 times above normal at 8 hours. Up to a 24-hour evaluation, no deaths were found. Previous studies using E. coli ATCC 11775 given intraperitoneally and evaluated at 0, 24, 48 and 168 hours [21], whereas this study did intravenously.

According to research, animals show calcitonin which has been successfully isolated in brain tissue, spleen, spinal gastric tissue, lungs, liver, and fat [22]. Other studies evaluated LPS and procalcitonin levels in mice for 10 days. The results obtained are procalcitonin appearing on days 3 and 4, while LPS appeared on day 7. This shows that besides LPS, there are other factors influencing the increase in procalcitonin levels [23]. Research on human samples showed that the group with suspected sepsis with positive procalcitonin had high leukocyte levels, which was a mean of 14.3 and in the

suspected group of sepsis with negative procalcitonin which had leukocyst levels of 9.3 [24]. A 2012 study using LPS at a dose of 1 mg/L in mice, and TNF α , IL-6 and IL-1 β cytokine levels were examined after 24 hours of administration. Significantly, cytokines all three increased compared controls. Examination to phosphorylation pathway specifically increases ERK 1/2, JNK and P38 MAPK levels after 30 minutes of LPS administration [25]. Increased IL-1B after administration of E. coli and decreased E. coli after administration of antibiotics showed that the inflammatory process was activated and inhibited by various pathways of piroptosis, caspase1, TLR4 DAMPs NLRP3 also occurred in the sepsis model of this study. In this study, researchers did not use LPS but E. coli ATCC bacteria. Variations in antibiotic administration and variations in the dose of E. coli exposure in this study provide information and strengthen previous research that the inflammatory pathway shown by IL-1ß levels also occurs in sepsis models of E. coli, and the timing of antibiotic administration can provide the best information on reducing levels IL-1β when it is a target for therapy. Previous study reported that significantly giving HSP10 can reduce LPS levels. The study evaluated that the administration of HSP10 can also reduce levels of cytokines IL-10, IL-4, IFNy [26]. In this study, HSP10 levels increased higher in the group without antibiotics. Precisely in the low dose E. coli dose group, there was an increase in HSP10 levels at 12 and 24 hours compared to the control and high E. coli dose. Previous studies also gave HSP10 at a dose of 100µg given 30 minutes before administering LPS at a dose of 10µg. There was a significant difference marked by a decrease in TNFα and an increase in IL-10 [26]. This study can also provide information that variations in antibiotic administration, ie early administration, when the sepsis marker is being delivered, and late administration, can provide additional information or strengthen research on HSP10. The increase in HSP10 in the group without antibiotics at 24 hours was most likely the HSP10 response in reducing E. coli. Provision of antibiotics provides information on the possible role of antibiotics in helping the work of HSP10 in reducing E. coli, or HSP10 markers can be a marker of resolution.

This study provides information that early antibiotic treatment accelerates resolvin D2 levels back to normal. The late administration of antibiotics actually causes resolvin D2 levels to go down at 72 hours. These results are in line with previous studies using sepsis models in mice with the CLP technique and comparing groups given resolvin D2 therapy.

Death occurred starting at 24 hours and almost 90% at 48 hours in the CLP group only. Meanwhile, the CLP group who were given resolvin D2 therapy could survive 80% until 36 hours and 60% from 48 hours to 120 hours [18]. These results are also in line with other studies that conducted research on giving resolvin D2 injection drastically can reduce inflammatory cytokines associated with prognosis namely IL-6, IL-1β, IL-23, TNFα.TNFα There is a decrease in bacteria, leukocytes, and PMN in the peritoneum. Giving resolvin D2 and resolvin D1 therapy has the potential to reduce leukocytes associated with the occurrence of microbial peritonitis from the 15th 60th minute. minute to the Without administration of resolvin D1 and resolvin D2 therapy, leukocytes continue to increase in the 15th minute, reaching a peak in the 60th minute. The study used a sepsis model in experimental animals with the CLP model. In that study, administration of resolvin D2 injection increased the survival of the sepsis model with CLP [27].

After seeing the evaluation of the four biomarkers and treatment groups by distinguishing the time of antibiotic administration, so if we have been using procalcitonin as a guide to starting and stopping antibiotics, then giving antibiotics at the 10th hour is the best. The IL-1B biomarker that we use as a mechanism for infalammasomes also has the same pattern as procalcitonin. This is in accordance with previous studies that toxins and LPS will directly trigger the release of procalcitonin, and various pro-inflammatory cytokines such as IL-1\u00e3, IL-6, and TNF α indirectly affect procalcitonin production [14]. Procalcitonin levels begin to increase 4 hours after the onset of systemic infection and reach a peak between 8 to 24 hours [28]. HSP10 in humans is encoded by the nuclear HSPE1 gene (geneID 3336) on chromosome 2q33.1. Intracellular proteins such as HMGB1 and IL-1ß can secrete extracellular signals from HSP10 secretion [29]. LPS via TLR4 activates NF-B, which further stimulates pro IL-1B with the help of cathepsin to activate NLRP-3 (inflammasome) stimulating Piroptosis through the active caspase-1 pathway and so can secrete IL-1B and IL-18 [30]. The existence of microbes that damage the tissue activates PMN; there is complete phagocytosis which will occur PMN apoptosis and stimulate the formation of SPM, then stimulate macrophages to inhibit edema. The other pathway which is not phagocytosis complete results in the formation of ROS captured by LTB4 receptors to secrete cytokines and chemokines, results in diapedesis, adhesion in blood vessels resulting in edema or extravasation and involves lipid mediators DHA and EPA to produce resolvin stimulate macrophages and inhibit edema. The occurrence of edema as an inflammatory response begins within a few minutes after germs enter, followed by PMN infiltration along with the emergence of SPM synthesizing lipoxins, resolvins, protectin, and maresin within a few hours to days [31]. After observing the dynamics of the four biomarkers in sepsis and statistically obtained differences in each group affected by *E. coli* doses and differences in the time to start antibiotics and without antibiotics, there is the potential for developing other biomarkers in sepsis other than procalcitonin.

This study has several limitations. The study design was limited to experimental animals so they could not evaluate for more blood sampling. Blood collecting was only a maximum of 3 times, including when animals were sacrificed. Provision of antibiotics could not be in accordance with the half-life required because it was limited to the time of giving outside working hours and experts who di.

CONCLUSION

The time of sepsis occurred at 8-10th hour. There were differences in levels of procalcitonin and resolvin D2 between groups at 24, 48, and 72 hours between the treatment of antibiotics at different times and without antibiotic administration. Meanwhile, there were differences the levels of IL-1β and HSP10 between groups at 24 and 72 hours, but there was no difference at 48 hours between the different antibiotic treatments and without antibiotics. Procalcitonin is a marker used as a guide to start and stop antibiotics in sepsis having the same pattern in all groups with IL-1\u03b2. Resolvin D2 and HSP10 have a slightly different pattern at 24 and 72 hours compared to procalcitonin and HSP10. Thus, it has the potential to be developed as a new biomarker in sepsis.

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